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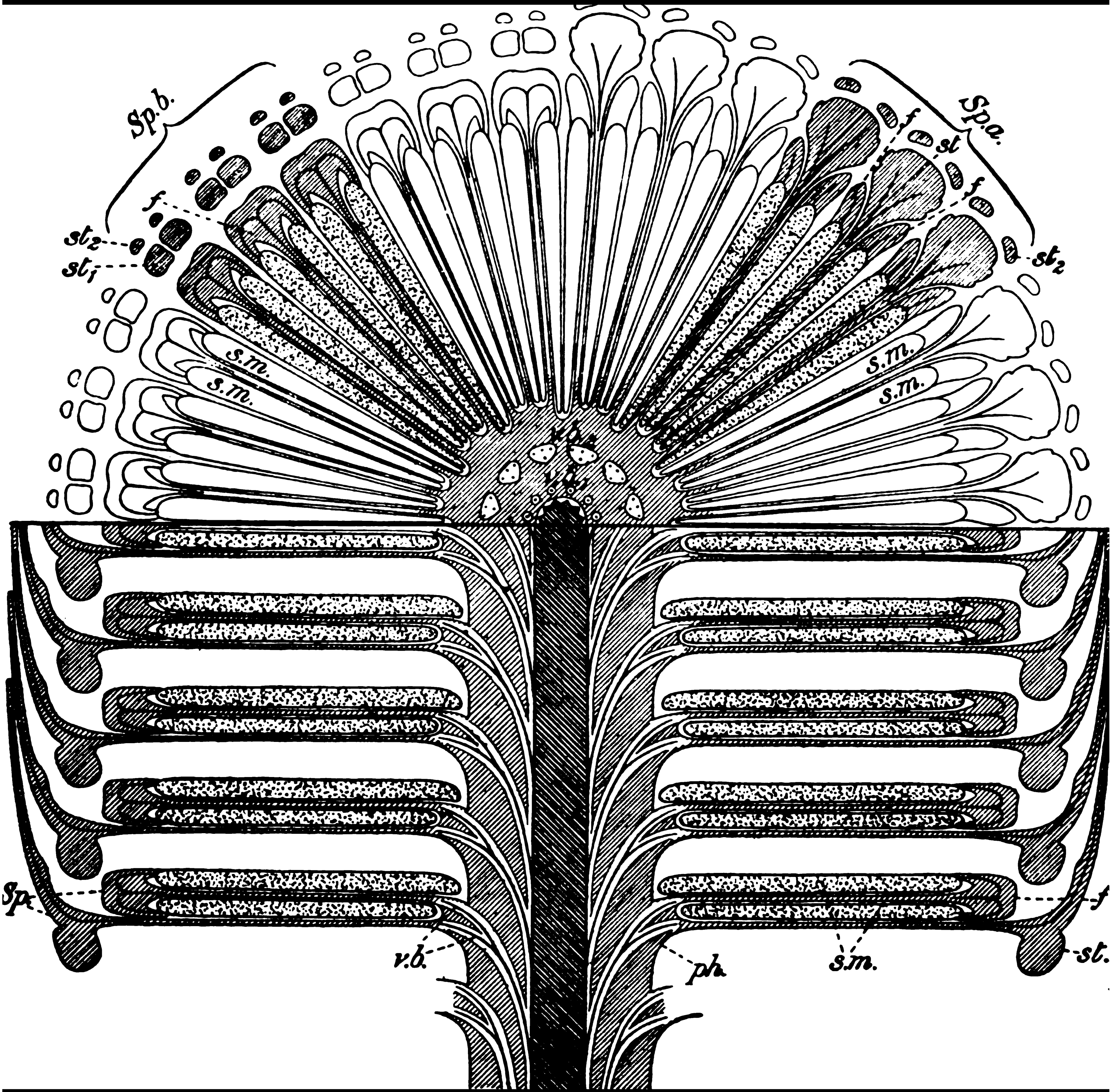

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  - *p.* Section Médicale de la Société des Sciences Expérimentales, Université de Kharkow.
- Kieff.
  - *p.* Société des Naturalistes.
- Moscow.
  - AB. Le Musée Public.
  - B. Société Impériale des Naturalistes.
- Odessa.
  - *p.* Société des Naturalistes de la Nouvelle-Russie.
- Pulkowa.
  - A. Nikolai Haupt-Sternwarte.
- St. Petersburg.
  - AB. Académie Impériale des Sciences.
  - B. Archives des Sciences Biologiques.
  - AB. Comité Géologique.
  - *p.* Compass Observatory.
  - A. Observatoire Physique Central.

Scotland.
- Aberdeen.
  - AB. University.
- Edinburgh.
  - *p.* Geological Society.
  - *p.* Royal College of Physicians (Research Laboratory).
  - *p.* Royal Medical Society.
  - A. Royal Observatory.
  - *p.* Royal Physical Society.
  - *p.* Royal Scottish Society of Arts.
  - AB. Royal Society.
- Glasgow.
  - AB. Mitchell Free Library.
  - *p.* Natural History Society.
  - *p.* Philosophical Society.

Servia.
- Belgrade.
  - *p.* Académie Royale de Serbie.

Sicily. (See ITALY.)

Spain.

Cadiz.
- A. Instituto y Observatorio de Marina de San Fernando.

Madrid.
- *p.* Comisión del Mapa Geológico de España.
- AB. Real Academia de Ciencias.

Sweden.

Gottenburg.
- AB. Kongl. Vetenskaps och Vitterhets Samhälle.

Lund.
- AB. Universitet.

Stockholm.
- A. Acta Mathematica.
- AB. Kongliga Svenska Vetenskaps-Akademie.
- AB. Sveriges Geologiska Undersökning.

Upsala.
- AB. Universitet.

Switzerland.

Basel.
- *p.* Naturforschende Gesellschaft.

Bern.
- AB. Allg. Schweizerische Gesellschaft.
- *p.* Naturforschende Gesellschaft.

Geneva.
- AB. Société de Physique et d'Histoire Naturelle.
- AB. Institut National Genevois.

Lausanne.
- *p.* Société Vaudoise des Sciences Naturelles.

Neuchâtel.
- *p.* Société des Sciences Naturelles.

Zürich.
- AB. Das Schweizerische Polytechnikum.
- *p.* Naturforschende Gesellschaft.
- *p.* Sternwarte.

Tasmania.

Hobart.
- *p.* Royal Society of Tasmania.

United States.

Albany.
- AB. New York State Library.

Annapolis.
- AB. Naval Academy.

Austin.
- *p.* Texas Academy of Sciences.

Baltimore.
- AB. Johns Hopkins University.

Berkeley.
- *p.* University of California.

United States (continued).

Boston.
- AB. American Academy of Sciences.
- B. Boston Society of Natural History.
- A. Technological Institute.

Brooklyn.
- AB. Brooklyn Library.

Cambridge.
- AB. Harvard University.
- B. Museum of Comparative Zoology.

Chapel Hill (N.C.).
- *p.* Elisha Mitchell Scientific Society.

Charleston.
- *p.* Elliott Society of Science and Art of South Carolina.

Chicago.
- AB. Academy of Sciences.
- *p.* Field Columbian Museum.
- *p.* Journal of Comparative Neurology.

Davenport (Iowa).
- *p.* Academy of Natural Sciences.

Ithaca (N.Y.).
- *p.* Physical Review (Cornell University).

Madison.
- *p.* Wisconsin Academy of Sciences.

Mount Hamilton (California).
- A. Lick Observatory.

New Haven (Conn.).
- AB. American Journal of Science.
- AB. Connecticut Academy of Arts and Sciences.

New York.
- *p.* American Geographical Society.
- *p.* American Mathematical Society.
- *p.* American Museum of Natural History.
- *p.* New York Academy of Sciences.
- *p.* New York Medical Journal.
- *p.* School of Mines, Columbia College.

Philadelphia.
- AB. Academy of Natural Sciences.
- AB. American Philosophical Society.
- *p.* Franklin Institute.
- *p.* Wagner Free Institute of Science.

Rochester (N.Y.).
- *p.* Academy of Science.

St. Louis.
- *p.* Academy of Science.

Salem (Mass.).
- *p.* American Association for the Advancement of Science.
- AB. Essex Institute.

San Francisco.
- AB. California Academy of Sciences.

United States (continued).

Washington.

- AB. Patent Office.
- AB. Smithsonian Institution.
- AB. United States Coast Survey.
- B. United States Commission of Fish and Fisheries.
- AB. United States Geological Survey.

United States (continued).

Washington (continued).

- AB. United States Naval Observatory.
- *p.* United States Department of Agriculture.
- A. United States Department of Agriculture (Weather Bureau).

West Point (N.Y.)

- AB. United States Military Academy.

ADJUDICATION of the MEDALS of the ROYAL SOCIETY for the year 1897, by the PRESIDENT and COUNCIL.

The COPLEY MEDAL to ALBERT VON KÖLLIKER, For.Mem.R.S., in recognition of his important work in Embryology, Comparative Anatomy, and Physiology, and especially for his eminence as a Histologist.

A ROYAL MEDAL to ANDREW RUSSELL FORSYTH, F.R.S., for his Contributions to the progress of Pure Mathematics, and especially for his work in Differential Equations and the Theory of Functions.

A ROYAL MEDAL to Lieut.-General Sir RICHARD STRACHEY, F.R S., for his Researches in Geographical, Meteorological, and Botanical Science.

The DAVY MEDAL to JOHN HALL GLADSTONE, F.R.S., for his numerous Contributions to Chemical Science, and especially for his important work in the Application of Optical Methods to Chemistry.

The BUCHANAN MEDAL to Sir JOHN SIMON, F.R.S., for his Distinguished Services as an Organiser of Medical Sanitary Administration in this country, and as a promoter of Scientific Research relating to Public Health.

The Bakerian Lecture, "On the Mechanical Equivalent of Heat," was delivered by OSBORNE REYNOLDS, M.A., F.R.S., and W. H. MOORBY.

The Croonian Lecture, "The Mammalian Spinal Cord as an Organ of Reflex Action," was delivered by CHARLES S. SHERRINGTON, M.D., F.R.S.

CONTENTS.

(B)

VOL. 189.

I. *On the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.—On* Cheirostrobus, *a new type of Fossil Cone from the Lower Carboniferous Strata (Calciferous Sandstone Series). By* D. H. Scott, *M.A., Ph.D., F.R.S., Honorary Keeper of the Jodrell Laboratory, Royal Gardens, Kew* . page 1

II. *Studies in the Morphology of Spore-Producing Members.*—III. *Marattiaceæ. By* F. O. Bower, *Sc.D., F.R.S., Regius Professor of Botany in the University of Glasgow* 35

III. *On the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.*—II. *On* Spencerites, *a new genus of Lycopodiaceous Cones from the Coal-measures, founded on the* Lepidodendron Spenceri *of* Williamson. *By* D. H. Scott, *M.A., Ph.D., F.R.S., Honorary Keeper of the Jodrell Laboratory, Royal Gardens, Kew* 83

IV. *On the Development of Marsupial and other Tubular Enamels, with Notes upon the Development of Enamel in General. By* Charles S. Tomes, *M.A., F.R.S.* 107

V. *On the Biology of* Stereum hirsutum (Fr.). *By* H. Marshall Ward, *D.Sc., F.R.S., Professor of Botany in the University of Cambridge* . . . page 123

VI. *An Investigation on the Variability of the Human Skeleton: with especial reference to the Naqada Race discovered by Professor* Flinders Petrie *in his Explorations in Egypt. By* Ernest Warren, *B.Sc. University College, London. Communicated by* W. F. R. Weldon, *F.R.S.* 135

Index to Volume 229

LIST OF ILLUSTRATIONS.

Plates 1 to 6.—Dr. D. H. Scott on the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.—On *Cheirostrobus*, a new type of Fossil Cone from the Lower Carboniferous Strata (Calciferous Sandstone Series).

Plates 7 to 11.—Professor F. O. Bower on the Morphology of Spore-Producing Members.—III. Marattiaceæ.

Plates 12 to 15.—Dr. D. H. Scott on the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.—II. On *Spencerites*, a new genus of Lycopodiaceous Cones from the Coal-measures, founded on the *Lepidodendron Spenceri* of Williamson.

Plate 16.—Mr. C. S. Tomes on the Development of Marsupial and other Tubular Enamels, with Notes upon the Development of Enamel in General.

Plates 17 to 21.—Professor H. M. Ward on the Biology of *Stereum hirsutum* (Fr.).

Plate 22.—Mr. E. Warren on the Variability of the Human Skeleton: with especial reference to the Naqada Race discovered by Professor Flinders Petrie in his Explorations in Egypt.

I. *On the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.—On* Cheirostrobus, *a new type of Fossil Cone from the Lower Carboniferous Strata (Calciferous Sandstone Series).*

By D. H. Scott, *M.A., Ph.D., F.R.S., Honorary Keeper of the Jodrell Laboratory, Royal Gardens, Kew.*

Received April 3,—Read April 8, 1897.

[Plates 1–6.]

Introduction.

The higher Cryptogamic Flora of the Palæozoic period was exceedingly rich compared with that of our own day. Confining our attention to those Cryptogams in which the fructification has the form of a definite cone or strobilus, we find that at least eight* distinct types of such strobili are already known from the primary rocks, leaving out of account all minor differences of a merely specific value, and ignoring imperfectly-known forms. From the recent Flora we could not obtain more than three equally distinct classes of Cryptogamic cones.

The fossil strobili at present discovered group themselves under three categories,—the Lycopodiaceous, the Equisetaceous or Calamarian, and the Sphenophyllaceous The two former coincide with well-known recent orders, while the last belong to a purely fossil group, at present only known from the Palæozoic formations, and so far of undetermined affinities.

The form about to be described is widely different from the fructification of any Vascular Cryptogam, recent or fossil, at present recorded, but it appears to approach the third group, that of the Sphenophylleæ, more nearly than either of the others.†

The bed which has yielded this specimen is one of great antiquity, belonging to the Calciferous Sandstone Series, at the very base of the Carboniferous formation, and therefore occurring at an horizon enormously more ancient than that of the Coal Measures, from which the majority of our specimens of Palæozoic plants have been derived. The deposit is at Pettycur, near Burntisland, on the Firth of Forth, and is already well known from the interesting vegetable remains, with structure preserved, previously obtained from it, among which may be mentioned *Sphenophyllum insigne*, *Heterangium Grievii*, *Rachiopteris duplex*, *Lepidodendron brevifolium*, and a *Lepidostrobus*, possibly of the same plant.* The great geological age of this deposit evidently gives a special interest to the fossil remains which it contains, among which it would not be surprising to find traces of synthetic types, combining the characters of orders of plants otherwise distinct. In the discovery of *Cheirostrobus* there is reason to believe that this possibility has been to some extent realised.

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* *Calamostachys, Palæostachya, Bornia, Cingularia, Sphenophyllum Dawsoni, Bowmanites Römeri, Lepidostrobus, Sigillariostrobus.*

† See preliminary paper "On *Cheirostrobus*, a new type of Fossil Cone from the Calciferous Sandstones," 'Proceedings Royal Society,' vol. 60, p. 417; 1897.

The only specimen of the cone at present known was found by Mr. JAMES BENNIE, of Edinburgh, in 1883. Sections of the specimen were in the possession of Mr. R. KIDSTON, F.G.S., to whom I am deeply indebted, as he not only called my attention to this fossil, but lent me his own sections for investigation, and obtained for me from the owner the remainder of the original block, which has yielded a number of new sections of great value.

As explained in the preliminary paper,† I had previously examined a fragment in the WILLIAMSON Collection, which has turned out to be, in all probability, the peduncle of another specimen of the same fructification. The peculiarities of this fragment were sufficient to show that it must have belonged to an undescribed plant, probably with some affinity to *Sphenophyllum*.‡ When, through Mr. KIDSTON'S kindness, I had the opportunity of investigating the actual cone, this conclusion became confirmed in a degree hardly to have been anticipated.

Although the examination of the peduncle came first in point of time, it will be more convenient, in the present memoir, to go on at once to the fructification itself, which is the object of chief interest, postponing the necessary details as to the peduncle to a later page.

The specimen is calcified, the block in which it occurs being of exceptionally uniform texture, and thus well suited for obtaining good sections. The structure is fortunately preserved with great perfection, so that from the solitary specimen a fairly complete knowledge of the strobilus can be obtained. I am informed that the original length of the fragment was about two inches. It includes the base of the cone, with part of its peduncle, but the apex is absent, and as dimensions and structure remain uniform so far as the specimen extends, we have no means of saying what the full length may have been. In its present state the cone is somewhat flattened, measuring about 5 centims. in greatest, by 2 to 2·3 centims. in least diameter. In parts the sporophylls have been a good deal displaced, but the flattening is due, not so much to crushing, as to the partial destruction of the appendages on two opposite sides (see Plate 1, photograph 1). From measurements of the most perfect portion, it appears that the diameter of the strobilus in its natural condition was at least 3·5 centims.

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* See WILLIAMSON, "Organisation of the Fossil Plants of the Coal Measures," 'Phil. Trans.,' 1871–93, *passim*.

† *Loc. cit.*, p. 417.

‡ 'British Association Report,' 1896, p. 1024.

GENERAL MORPHOLOGY.*

The axis of the cone maintains, throughout the specimen, a diameter of about 7 millims. Its appendages are borne in somewhat crowded verticils; fourteen of such verticils occupied a portion of the axis about an inch (2·5 centims.) in length. The members of successive whorls are not alternate, but superposed, lying exactly above each other in vertical lines. This important point is shown most decisively in tangential sections of the cone, such as that represented in Plate 1, photograph 6, with which Plate 2, photograph 8, may be compared. The number of members in each whorl was twelve. The whole number is not shown in any one transverse section, but follows from the number and arrangement of the leaf-traces, and their relation to the appendages, as shown for example in Photograph 2. The axis is traversed by a vascular cylinder, the wood of which is polyarch, with twelve prominent angles, each of which corresponds to one of the vertical series of appendages (see Plate 1, photographs 1-3). The exact relation of the anatomy to the external organisation will be fully considered below.

The appendages may be called sporophylls, as they are foliar structures, which ultimately bear the sporangia. Their organisation, however, is remarkably complex, more so than in any strobiloid Cryptogam at present known.

The length of each sporophyll, from its insertion on the axis to its distal extremity, was about 1·4 centim., as determined from the best-preserved parts of the specimen. Its general direction, when not displaced, was horizontal; at the base of the cone, however, where the appendages are shorter, they have a downward inclination (see Plate 3, photograph 15). These basal sporophylls will be dealt with afterwards; at present only those of the ordinary form, such as occupy the greater part of the strobilus, will be considered.

The sporophyll remains undivided for only a very short distance from its insertion. The leaf-base, or phyllopodium,† which has a slight upward slope, is about 1 millim. long—its transverse section (shown in tangential sections of the cone) is roughly oblong, with a width of about 2 millims., and a height of nearly 1 millim. (see Plate 1, photographs 4, 5, and 6; Plate 2, photograph 7). The leaf-bases of the same verticil are distinctly connate, so as to form a continuous ring round the axis (see Photographs 2 and 6).

The sporophyll, at a distance of about a millimetre from the axis, divides into an upper and a lower lobe or limb, the one placed directly above the other (see Photo-

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* See, in addition to the photographs and figures, the diagram of the cone on p. 7.

† BOWER, "Comp. Morph. of the Leaf in Vasc. Cryptogams and Gymnosperms," 'Phil. Trans.,' 1884, Part II., p. 569.

graphs 4, 5, 6, and 7). Each lobe immediately undergoes subdivision in a palmate manner, into three segments, so that a normal sporophyll consists of six segments in all, three of which belong to the upper and three to the lower lobe. These subdivisions are best observed in tangential sections of the cone, passing through the region of the sporophyll bases (see Photographs 6 and 7). Occasionally the number may be less than six, especially at the bottom of the cone, but the six segments, three inferior and three superior, are the rule.

The segments, or leaflets, have a very peculiar form: each consists of a long, straight, slender petiole, or more correctly, petiolule,* the average diameter of which is only about ·35 millim. (Plates 1–3, photographs 4, 5, 8, 9, and 14). This extends horizontally for a distance of a centimetre or more, and then terminates in a relatively large laminar expansion. The segments are of two kinds, the one fertile, bearing the sporangia, the other sterile. So far as the petiolules are concerned, the fertile and sterile segments are almost exactly alike, but their laminæ are very different (Plates 2 and 3, photographs 9–13).

The fertile segment, or *sporangiophore*, as it may conveniently be termed, has a bulky lamina, the general form of which is peltate, but with a somewhat complex contour (see photographs above cited) and considerable thickness. On its inner or adaxial side the lamina bears (in most cases at least) four diagonally placed outgrowths, on each of which a sporangium is borne. The number of sporangia on each sporangiophore has been determined chiefly from the comparison of radial and transverse sections, in both of which views the attachments of two sporangia are usually shown (see Photographs 9 and 12), and also from the grouping of the sporangia around the petiolules, as shown in tangential sections (Photograph 14). In some cases *three* sporangia are shown in the radial section of a sporangiophore (Photograph 9, $f.^4$); this may be merely due to displacement, or may indicate that five in all may occasionally have been present.

The sporangia are long and narrow, extending back along the petiolules, so as nearly or quite to reach the axis (see Photographs 1 and 4). As the axis is approached the space available obviously diminishes, and to accommodate themselves to these conditions, about half the sporangia stop short of the axis,† while the remainder extend quite to its surface, fitting into the spaces between the sporophyll-bases and their segments (Photographs 2, 5, and 7). The sporangia thus have a curiously elongated form, for, roughly speaking, they are about a centimetre long, by about a millimetre in mean diameter (Photograph 4). At the outer end a sporangium may measure about 1·5 millim. in its horizontal diameter, but it tapers towards the axis to a more or less pointed extremity.

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* In the preliminary paper the word *pedicel* was used for these organs, from analogy with the sporangiferous pedicels of *Sphenophyllum*. It seems preferable, however, to adopt a term more in harmony with the foliolar nature of the segments.

† Shown by the diminished number of sporangia, as compared with that of the petiolules, in tangential sections approaching the axis.

The fertile laminæ fit pretty closely together both as seen in radial and transverse section (see Photographs 9 and 12). The sterile segments, however, are longer than the sporangiophores, and their laminæ overlap those of the latter. The arrangement of sterile and fertile segments is such that they alternate regularly with each other in the same vertical series, as shown in a radial section such as that represented in Photograph 10. As the fertile laminæ are of sufficient dimensions to occupy by themselves the whole of the available space, it is evident that they must be grooved on their upper and lower surfaces so as to allow the sterile segments above and below them to reach the exterior. That this is so is shown by radial sections, where the sterile lamina is often seen encroaching on its fertile neighbour (Photographs 9, *st.*^{4}, and 11 *st.*), and by transverse sections, such as that shown in Photogragh 13, where the two lateral wings of a fertile lamina are seen with the sterile segment passing between them. Indications of the arrangement can also be seen in tangential sections, but, unfortunately, such sections through the region of the laminæ are rarely satisfactory. The transverse section shown in Photograph 12 cuts the fertile laminæ in a more median plane, so as nearly to miss the groove.

Before further considering the relative positions of the fertile and sterile segments we will complete the description of the latter.

The sterile segment begins to widen out as it passes through the groove of the fertile lamina and spreads out beyond it, as seen in transverse sections of the cone (Photograph 13) into a kite-shaped blade with lateral lobes. The comparison of radial with transverse sections, however, shows that the sterile lamina is really of a very complex form. On its under surface it has a pair of blunt downward projections, placed side by side, which cover the external surface of the fertile lamina next below (see Photographs 10, *st.*^{3}, and 11, *st.*). In the opposite direction the apex of the lamina divides into two more slender prolongations, which turn upwards, overlapping the sterile lamina next above, and extending up for a distance equal to several internodes. In this particular the account given in the preliminary paper requires modification, for both the "upturned foliaceous scale" and the "shorter and stouter downward prolongation" there spoken of* are really double. This is seen very clearly in transverse sections, as in that shown in Photograph 12, *st.*^{1}, and *st.* Outside the fertile lamina *f.*^{1}, we see two pairs of appendages cut transversely. The inner pair, which are the larger, and consist of somewhat large-celled tissue, represent the downward prolongations of the sterile lamina next above; while the outer pair, which are rather smaller, and of denser structure, represent the upward prolongations of the sterile lamina next below. The comparison with the radial section (Photographs 10 and 11) shows clearly that this is the right interpretation (see the

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* *Loc. cit.*, p. 420.

DESCRIPTION OF DIAGRAM.

The upper part of the diagram shows half the cone in transverse section; the lower part is shown in radial section; the position of the various organs corresponds in the two sections.

1. Transverse section. Six complete sporophylls are shown, each with three segments. The three sporophylls to the left are represented as in median section through the *fertile* segments (*f.*); the three to the right as in median section through the *sterile* segments (*st.*). On each side one sporophyll is shown in detail. *s.m.*, sporangia.

    Sp. b. One sporophyll, showing the three peltate fertile segments, or sporangiophores, united at the base. Two sporangia are shown inserted on each lamina, and extending almost to the axis. To the outside of each fertile lamina are seen the two downward outgrowths (*st.*$_1$) of the sterile segment next above and the apices (*st.*$_2$) of that next below (*cf.* Photograph 12).

    Sp. a. One sporophyll, showing the three foliaceous sterile segments. Each of these passes through the groove of a fertile lamina, the two lobes of which (*f.*, *f.*) (bearing sporangia) are seen to the right and left of each sterile lamina where it begins to expand. To the outside are seen the double apices of the sterile segments next below (*st.*$_2$) (*cf.* Photograph 13).

    In the axis the stele, and two verticils of leaf-traces are shown, the inner undivided (*v.b.*$_1$), the outer after division into four bundles each (*v.b.*$_2$) (*cf.* Photograph 2).

2. Radial section. The sporophylls are separated from one another by a space which does not exist in nature, in order to show their form more clearly. Each sporophyll (as at *Sp.*) is drawn on the assumption (probably correct) that the upper segments (*f.*) are fertile, and the lower (*st.*) sterile.

    ph. Base, or phyllopodium, of a sporophyll; *f.*, one of its peltate fertile segments, on which two sporangia are visible; *st.*, a foliaceous sterile segment (*cf.* Photographs 9–11). *Ax.*, axis; *cy.*, stele. Note the antero-posterior division of the leaf-trace bundles (*v.b.*) (*cf.* Photographs 4 and 5). *s.m.*, sporangia.

The representation, while strictly diagrammatic, is in all essentials true to nature, and is drawn approximately to scale, about four times natural size.

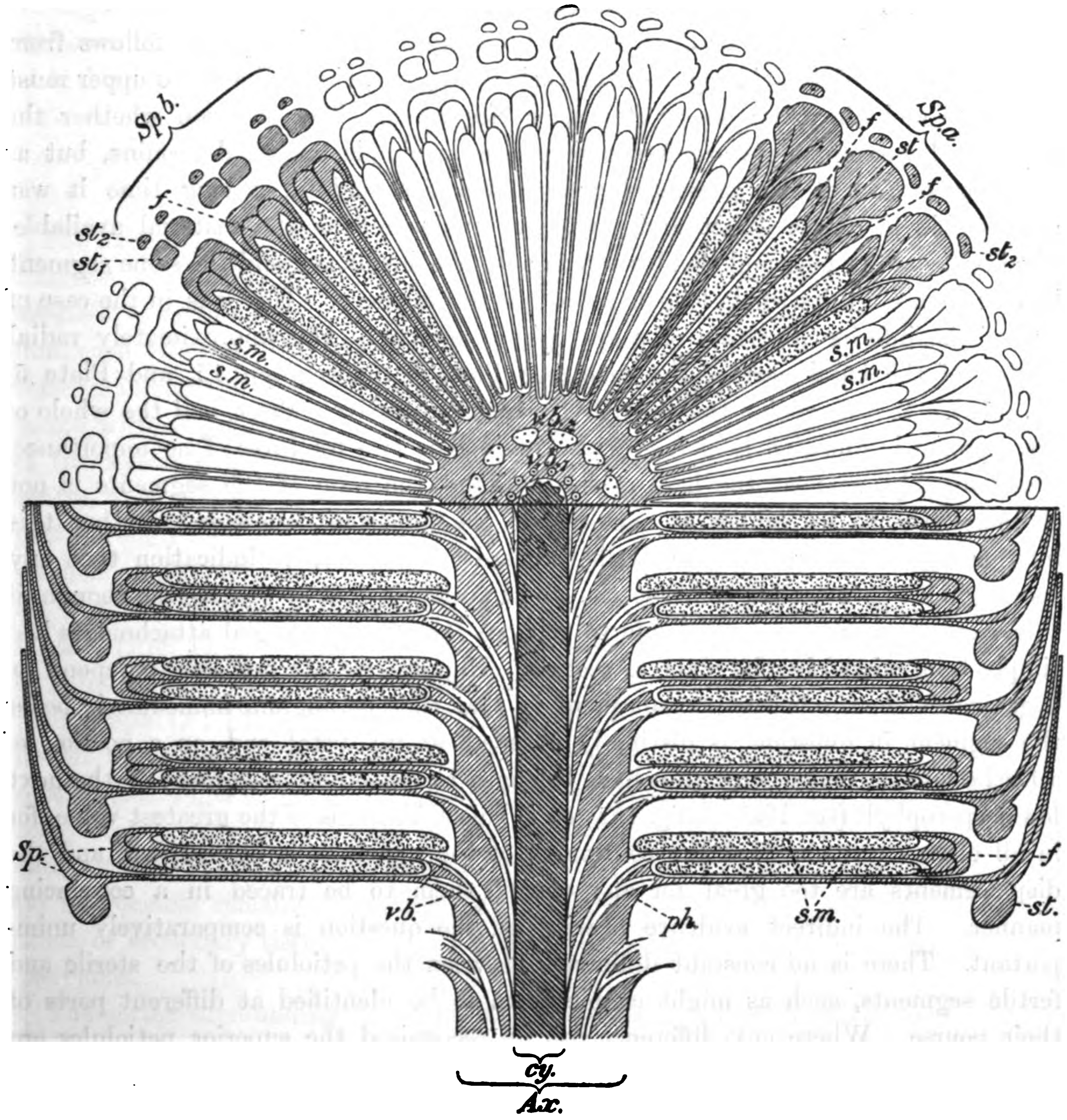

Diagram of Cheirostrobus Pettycurensis.

diagram, p. 7). With this elaborate system of fertile and sterile laminæ, it is evident that the exterior of the cone was very efficiently protected.

The sterile and fertile segments, as we have seen, are placed alternately one above the other, so that in every vertical series there is an equal number of each kind. In the transverse plane there is no alternation. At the same level all the segments cut medianly are sterile or all fertile (Photographs 12 and 13). It follows from these facts that of the six segments of each sporophyll, either the three upper must be fertile and the three lower sterile, or *vice versâ*. The question whether the upper or lower segments are fertile may seem a simple one to determine, but as a matter of fact it has presented great difficulties, and for a long time it was not possible to obtain direct and conclusive evidence from the material available. The segments are long and slender and in only one instance could the same segment be traced through its whole length from axis to periphery. This was in the case of one of the inferior segments of a sporophyll, shown in the approximately radial section of the basal part of the cone (see Plate 3, photograph 15, and Plate 5, fig. 15A). In this region the sporophylls are comparatively short, and the whole of the segment in question is shown, with only one or two fractures of no importance. Unfortunately, so near the base of the strobilus the form of the segments is not characteristic, so we cannot at once decide the important question, whether this inferior segment was fertile or sterile. There is, however, no indication that any sporangium was attached to it, so the presumption is that it was sterile, though, if this were all, it might be possible to suppose that the sporangial attachments had simply been missed by the plane of section. Happily, we are not left to depend on negative evidence; the important point is, that the sporangium immediately *below* the segment in question, is distinctly inserted, at its distal end, on a portion of a fertile lamina, which must thus have belonged to the *superior* segment of the next lower sporophyll (see Plate 5, fig. 15A, *a*). This evidence is of the greatest value, for in all other cases observed the continuity of the segments is interrupted, and the displacements are too great for any one of them to be traced in a convincing manner. The indirect evidence bearing on the question is comparatively unimportant. There is no constant difference between the petiolules of the sterile and fertile segments, such as might enable them to be identified at different parts of their course. Where any difference can be recognised the superior petiolules are found to be rather the larger (as seen at the proximal end), and the fertile petiolules rather the larger (as seen at the distal end). This supports the identification of the upper with the fertile segments, but no great stress can be laid on such trifling distinctions.

We shall see below that the evidence from the course of the vascular bundles indicates that the inferior segments probably represent the vegetative part of the sporophyll, just as is the case in *Sphenophyllum Dawsoni*.* Analogies, however,

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* WILLIAMSON and SCOTT, "Further Observations on the Organization of the Fossil Plants of the Coal Measures," Part I., 'Phil. Trans.,' B, 1894, p. 937.

might be cited in support of either view; if we compare our cone with the plant just mentioned, we must expect to find the sporangiophores in the superior position; but in *Cingularia* we find a good example of the opposite arrangement. On the whole, I think, the evidence, though depending chiefly on a single instance, strongly in favour of the conclusion that in each sporophyll the upper segments are fertile and the lower ones sterile. The mode of overlapping of the laminæ also harmonizes best with this interpretation.

ANATOMICAL STRUCTURE.

The Axis.

The axis of the strobilus is traversed by a central cylinder about 2·4 millims. in diameter, of which the wood only is preserved. The structure is dodecarch, the smallest elements occurring at the twelve prominent angles, which are separated from each other by deep furrows (Photographs 2 and 3). Towards the interior the tracheæ increase in size, and become more laxly arranged, having no doubt been intermixed with conjunctive parenchyma, of which little trace has remained. The interior of the xylem is not perfect, but enough remains to show that it extended to the centre, so that no pith existed (Photograph 3). Longitudinal sections, where they pass through one of the projecting angles of the xylem, show the narrow spiral tracheæ at the periphery, proving the centripetal development of the wood (Plate 4, fig. 1).* Advancing inwards from the protoxylem we find the tracheæ reticulately marked (Fig. 1), and further towards the interior they all show several rows of round or elliptical pits, on which, in favourable cases, the border can be detected (Plate 3, photograph 17; Plate 4, fig. 2). Many of the more internal tracheæ are short, with horizontal transverse walls, on which a reticulate thickening is evident in transverse section (see Figs. 3 and 3A), recalling the well-known structure of *Lepidodendron selaginoides*. The lateral walls of these short tracheides often differ somewhat from those of the long ones, having a reticulate rather than a pitted structure. There are no appreciable remains of phloëm, nor is there, in the axis of the cone itself, any trace of secondary tissues, though, as we shall see, such tissues were formed in the peduncle.

The cortex surrounding the stele has an undulating inner limit, the bays of which correspond to the prominent protoxylem-angles (see Photographs 2 and 3). We will next follow the course of the leaf-trace bundles, postponing the detailed anatomy of the cortical tissues.

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* In this case the most disorganized tracheæ lie a short distance within the extreme edge—an appearance which recurs at several points, and which can hardly be explained altogether by deviation of the section from the radial plane. It is probable that after the differentiation of the very first protoxylem-elements one or two tracheæ may have been added to the outside, possibly in connection with the insertion of the leaf-trace bundles. In any case the centripetal development of the primary wood, as a whole, is not affected.

From each of the twelve prominent angles of the stele a single vascular bundle passes outwards, having at first only a slight upward inclination, and bending more sharply upwards as it enters the cortex (see Plate 1, photographs 3 (*l. t.*) and 5; Plate 4, fig. 4). The insertions of the leaf-traces on the stele form vertical series, the xylem angles running without interruption through the nodes (as in *Sphenophyllum*), and not forming a reticulum as in *Lepidodendron** (see Photographs 4 and 8). The wood thus has the form of a fluted column. This characteristic arrangement is obviously correlated with the superposition of the foliar whorls.† The course of the outgoing leaf-trace extends through two internodes, or rather more, so that the traces of two successive whorls, sometimes with part of a third, appear in the same transverse plane. The existing transverse sections of the cone are really somewhat oblique, the difference in level of two opposite sides nearly equalling the length of an internode. This is a fortunate circumstance, as it enables us to follow the changes which the bundles undergo at every part of their outward course (see Photograph 2). The tangential sections likewise are somewhat inclined to the axis, so that in this view also the whole course of the traces is revealed by comparing the successive members of the same vertical series (see Photograph 8).

The single bundle, which is destined to constitute the vascular supply of one sporophyll, begins to subdivide when about one-third of the way through the cortex (see Plate 1, photograph 2, and Plate 4, fig. 6). The division is into three bundles, lying at first in the same tangential plane. Sometimes one of the two lateral bundles is given off a little before the other. The median bundle is much the largest of the three, for it has to undergo further sub-division. The three bundles gradually diverge from one another, and when about half-way through the cortex the median one divides again, but in a plane at right angles to that of the first division, so that one branch is posterior and the other anterior (see Photographs 2, 5, and 8, Plates 1 and 2; figs. 7, 8, and 9, Plate 4).

The posterior or upper branch is here the larger, for it is this which still has further divisions before it. Almost at the level where the three anterior bundles begin to leave the stem and enter the sporophyll-base, the posterior bundle itself subdivides into three, just in the same way as in the first branching (Photograph 2). There are thus six bundles in all—three lower or anterior, and three upper or posterior. All six enter the base of the sporophyll, as is shown with the greatest clearness in such tangential sections as that represented in Photographs 6 and 7. The three anterior bundles pass out into the three inferior segments, and in like manner the three superior segments (probably the sporangiophores) are supplied by the three posterior bundles.

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* BERTRAND, 'Remarques sur le *Lepidodendron Harcourtii*,' 1891. HOVELACQUE, 'Recherches sur le *Lepidodendron selaginoides*,' 1892. RENAULT, 'Tiges de la Flore Carbonifère,' 1879, p. 258.

† *Cf.* SOLMS-LAUBACH, 'Fossil Botany,' Engl. Ed., p. 348; "Bowmanites Römeri, eine neue Sphenophylleen-Fructification," 'Jahrbuch der K. K. Geolog. Reichsanstalt,' 1895, p. 241.

Irregularities are seldom observed; in one case (slide K, 84^c*) only two bundles are present after the first division, where there should normally be three. In the trace immediately outside this only two posterior bundles are visible instead of three, so it seems that at least two successive leaves had this peculiarity, which, however, does not appear in other sections. At the base of the cone, however (Photograph 15, Plate 3), there seems to have been only two bundles (and no doubt the same number of segments) to each lobe.

Elsewhere the sub-divisions of the leaf-trace take place with diagrammatic regularity.

As regards the details of structure of the leaf-trace bundles there is not much to be said. Near the stele the undivided bundles certainly seem to be collateral, for the xylem adheres closely to the inner side of the gap, which has presumably been left by the decay of the phloëm. A little further out, but before the first sub-division, the xylem takes up a more central position, surrounded by thin-walled tissue. Probably this tissue was only in part of the nature of phloëm, the outer zone being parenchymatous (peridesm of VAN TIEGHEM). The distinction can be detected in Plate 4, fig. 6, but it is more marked in the base of the sporophyll (Plate 5, figs. 10 and 11). The presumption, however, is that the leaf-trace bundles, except where still quite close to the central cylinder, had a concentric structure.

The position of the first-formed tracheæ of the bundle is by no means evident, but was most probably central (Figs. 9 and 10). Usually, all the tracheæ are spirally thickened, but in the clearer cases the more central are the smaller, and in the longitudinal section just referred to a lax spiral is seen in the middle of the xylem strand.

I find no difference in orientation or structure between the bundles of the upper and lower lobes, a point to which special attention has been directed. It will be noticed that it is only after all the three bundles for the inferior segments have separated that those for the superior segments are given off. It is this fact which appears to indicate that the lower segments represent the main part of the leaf, just as is the case in the strobilus of *Sphenophyllum Dawsoni.*

The structure of the cortex of the axis is fairly uniform throughout, consisting of slightly elongated, rather thick-walled cells, becoming smaller towards the outside. As seen in transverse section, the cortex appears marked out into areas, each enclosing a bundle, or a group of bundles, belonging to the same leaf-trace (see Photograph 2). The cells forming the boundaries of these areas are slightly compressed.

The most characteristic point in the structure of the cortex is the presence of large elements, with dense brown or black contents (see Fig. 4, *ss.*). In longitudinal sections we see that they are long sacs, with pointed ends, and are sharply distinguished from the ordinary parenchyma. We may provisionally regard these elements as of the nature of secretory sacs (Fig. 5, *ss.*). They are most conspicuous in the inner cortical layers. On the exterior the cortex is bounded by a well-defined small-celled epidermis (Fig. 7, *ep.*).

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* [The numbers referring to slides in Mr. KIDSTON's collection are preceded by the letter K; those referring to my own collection, by the letter S.—Sept. 24, 1897.]

The Sporophylls.

The bases of the sporophylls consist of tissue quite like that of the cortex of the axis (Photographs 5 and 7). The six vascular bundles in each base are well shown, especially those running to the upper segments (see Plate 2, photograph 7; Plate 5, fig. 10). In each bundle the xylem, which has its smallest elements towards the centre, is surrounded by a very delicate small-celled tissue, which was no doubt the phloëm.* This again is enclosed in a large mass of thin-walled parenchymatous cells. Here, as in the axis, the bundle appears to be concentric, but lies towards the upper surface of the parenchymatous envelope.

The bundles belonging to the lower segments are similar, but in the few cases where their structure can be made out at all clearly, the xylem-group seems to be rather smaller, and the phloëm less well-defined (see Fig. 11). No great stress can be laid on such differences, but so far as they go they support the conclusion that the upper segments most probably supplied the sporangia, which would make a much greater demand on their conducting tissues than would the barren laminæ of the other segments. The tissue of the sporophyll-base is abundantly supplied with "secretory sacs," especially around the vascular bundles.

Nothing need be said as to the anatomy of the petiolules of the segments. Owing to the growth of the sporangia packed between them, they are all more or less compressed, and little structure can be made out. Here and there the vascular bundle running through each petiolule can be traced.

The laminæ, however, are well preserved, and present some characteristic features. We will take the fertile laminæ first.

When the petiolule begins to widen out into the lamina, its vascular bundle at once bifurcates into two diverging branches, lying in the same radial plane (see Plate 5, fig. 12, *vb.*). Each branch of the bundle again divides, and the four ultimate vascular strands curve sharply back, each running to the base of a sporangium (see Fig. 12, *vb'.*). The whole arrangement is closely similar to that in a *Calamostachys*† or a *Palæostachya.*

In *Cheirostrobus* each sporangium is seated on a short but definite stalk, which ensheaths its base. Hence, when the stalk is cut tangentially, it appears longer than when the section passes through its median plane (see Plate 2, photographs 9 and 10; Plate 5, fig. 12). It is not easy to fix the limit between the sporangium and its stalk, for the characteristic sporangial wall runs up for a little way over the tissue of the stalk, especially on the side towards the petiolule of the sporangiophore (Fig. 12). There is a considerable resemblance to the mode of attachment of the sporangium in *Sphenophyllum Dawsoni* and in *Bowmanites Römeri.**

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* The structure of the vascular bundles is not unlike that of the foliar bundles in some species of *Selaginella.* See HARVEY GIBSON, "Anatomy of the Genus *Selaginella*," Part 3, 'Annals of Botany,' vol. 11, 1897, Plate 9.

† WILLIAMSON and SCOTT, "Further Observations," Part I., plate 81, figs. 29 and 32; also WILLIAMSON, "Organization," Part XI., pl. 54, fig. 23, and Part XV., plate 2, fig. 8.

The parenchyma of the sporangial stalk is very delicate; that of the peltate lamina itself is formed of large cells, with thicker walls, interspersed with secretory sacs (Photographs 9–12, fig. 12). Some of the elements have the look of stone-cells, but this appearance is probably due to a peculiar alteration in the cell-contents of some of the sacs.

The resemblances between the fertile lamina in *Cheirostrobus* and the peltate scale of a *Calamostachys* are too great to be ignored. In the former the lamina is rather thicker, and the peltate shape less neat; possibly we have here a somewhat more primitive form of the peltate sporangiophore.

The vascular bundle of the sterile, like that of the fertile segment, bifurcates at the base of the lamina, but here the two branches lie in the same transverse plane (Photograph 13). They pass out into the two upturned prolongations, in which they can be recognised both in radial and transverse sections. On the other hand, the blunt, downwardly-directed outgrowths appear to contain no vascular tissue; they consist of rather large-celled parenchyma, with secretory sacs (Photograph 11). The tissue of the main part of the sterile lamina is similar to that of the fertile segment. The upward prolongations contain fibrous sclerenchyma outside the bundle, and towards the apex the fibrous tissue constitutes almost the whole of the organ.

The Sporangia and Spores.

The structure of the sporangia, in spite of their great size, is exceedingly simple. The wall, as preserved, consists of a single layer of cells, except at the point of insertion, where as already pointed out, the stalk passes gradually over into the sporangium. The absolute thickness of the wall is about ·025 millim., and is fairly constant in all parts. The constituent cells of the wall are much elongated in the direction of the long axis of the sporangium. Their cell walls are excessively delicate, but are stiffened by buttresses which stand out from the radial walls at right angles, and extend throughout the whole height of the cell, becoming broader towards its inner surface. The buttresses on either side of the same radial wall are usually opposite each other, but sometimes alternate (see Fig. 13). It will be seen that this characteristic structure is precisely the same as that of the sporangial wall of a

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* WILLIAMSON, "Organization," Part XVIII., plate 27, fig. 16; WILLIAMSON and SCOTT, "Further Observations," Part I., plate 86, fig. 58; SOLMS-LAUBACH, "*Bowmanites Römeri*," plate X., fig. 5.

Calamostachys. The agreement is especially close with *C. Ludwigi*, CARR, where the cells of the wall have the same elongated form as in *Cheirostrobus.*[*]

There is also a close resemblance to the sporangial wall of *Sphenophyllum Dawsoni.* Taken in connection with the whole organization of the sporangiophores, these detailed resemblances to Calamarieæ and Sphenophylleæ seem to me to have an important bearing on the affinities of our fossil. The massive base on which each sporangium is borne, appears to indicate that its development must have been of the "eusporangiate" type, *i.e.*, that a number of initial cells took part in its formation.

The weak mechanical construction of such large sporangia (far larger than any known to us among recent Cryptogams) may seem surprising, but was no doubt compensated for by the way in which the sporangia are densely packed, so as to support each other, the whole mass being held together by the investiture of the peripheral laminæ.

If we confine our attention to the sporangiophores and sporangia, it may be said with confidence that there is no essential difference, so far as these organs are concerned, between *Cheirostrobus* and a Calamarian fructification of the *Calamostachys* type. Taking the position of the sporangiophores into account there is a still more striking analogy with *Palæostachya.*

The spores are of uniform size and structure in all parts of the specimen, including the sporangia at the base of the cone (compare Fig. 14 with Fig. 15B). This specimen therefore affords no evidence of heterospory. The average diameter of the spores, determined by a large number of measurements, is ·065 millim. The variations on either side of the mean are inconsiderable, and were no doubt even less in life than they appear in the necessarily somewhat distorted spores of the fossil.

The spores are approximately spherical in form ; the membrane generally is thin, but marked by conspicuous thickened ridges, dividing up its surface into four areas. The ridges in all probability correspond to the lines of junction of the four spores of a tetrad ; three of the areas would thus have been occupied by the three sister-cells, the fourth being free. The arrangement of the spores would thus appear to have been tetrahedral, but they have not been found actually united in tetrads (see Plate 3, photograph 16 ; Plate 5, figs. 14 and 15B). No remains of any cellular body within the spore, nor indeed of any cell-contents, could be detected.

In the less well-preserved parts of the specimen the thin membrane of the spores has to a great extent perished, leaving little more than the thickened ridges, which are often partly straightened out, and grouped so as to form an irregular mesh work ; the appearance presented in these cases is very different from that of the uninjured spores (see Fig. 12).

As regards the dimensions of the spores, they are much larger than the microspores of most *Lepidostrobi*, though not much exceeding those of *L. Brownii*, and are nearly as large as those of *Calamostachys Casheana*. They are somewhat smaller than the spores of the homosporous *C. Binneyana* and than those of *Sphenophyllum Dawsoni*.

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[*] C. E. WEISS, "Steinkohlen-Calamarien," II., in 'Abhandlungen z. Geologischen Specialkarte v. Preussen,' vol. 5, Heft II., 1884, Plate 23, fig. 2, and plate 24, figs. 3, 4, and 5; WILLIAMSON and SCOTT, "Further Observations," part I., 1895, p. 909, plate 81, fig. 31.

The Peduncle.

The peduncle on which the cone was supported remains to be described. The description will be based in the first instance on the specimen in the WILLIAMSON collection. and the evidence for the identification of this specimen with *Cheirostrobus* will then be stated. A good description of the general structure of this fragment was given by WILLIAMSON in 1872, but he was under the mistaken impression that it might belong to the Burntisland *Lepidostrobus*.*

The diameter of the specimen is about 7 millims. which agrees with that of the axis of the cone. It is traversed by a polyarch stele about 2 millims. in diameter (Plate 3, photograph 18; Plate 6, figs. 18 and 20). The number of prominent xylem-angles varies from twelve to nine in the different transverse sections. When the number is less than twelve we find that one or more of the angles are blunt, and sometimes evidently double, representing a fusion of two prominences (Fig. 20). The interior of the stele is solid, and occupied by intermixed thick-walled and thin-walled elements; the longitudinal sections show that the former are tracheæ, the latter conjunctive parenchyma (Figs. 22 and 23). There is thus no medulla, the wood extending to the centre.

A well-marked zone of secondary tissue is present, the thickness of which varies, both in the different sections and in different parts of the same section (see Photograph 18; figs. 20 and 21). In the section with twelve xylem-angles (Cabinet Number 539) the maximum thickness of the secondary wood is six elements; while in the sections with nine or ten angles it has attained in places to a thickness of ten tracheæ. It is probable that the number of angles increased, and the thickness of the secondary wood diminished, from below upwards; for we know that in the axis of the cone itself (judging from our solitary specimen) the stele was dodecarch, and without any secondary formations.

In all the sections the secondary zone is more or less incomplete, extending round the greater part, but not quite the whole, of the periphery of the stele. It is not limited to the furrows, but extends also round the angles of the primary wood (Fig. 20), though sometimes with a diminished thickness at these points.

In the primary xylem the smallest elements are placed at the prominent angles. Sometimes where an angle is very obtuse, two distinct groups of small tracheæ are present, showing that the angle in this case is really a double one. Radial sections show that the small peripheral elements are spiral tracheæ (Fig. 22), and thus represent the protoxylem. Here, as in the axis of the cone, there is some reason to doubt whether differentiation of the xylem began absolutely at the exterior, for sometimes the smallest elements are bounded externally by one or two slightly larger ones, which seem still to belong to the primary wood. In any case the differentiation must have been almost wholly centripetal.

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* WILLIAMSON, "Organization," Part III., p. 297. See Preliminary Paper on *Cheirostrobus*, 'Proc. Roy. Soc,' vol. 60, p. 418.

The tracheæ of the interior of the stele are not scalariform, but bear several rows of rounded or polygonal pits, which, as shown in the clearer cases, are distinctly bordered (Figs. 22 and 23). At some places the tapering ends of the tracheides are seen. Some of the more central tracheides are square-ended, but not so commonly as in the axis of the cone. The parenchymatous cells intermixed with the tracheæ are sometimes well preserved. Some of these elements are filled with dark brown contents, and may have been of a secretory nature.

The secondary wood is at once distinguished from the primary by the regular radial seriation of its elements ; between the series of tracheæ distinct medullary rays are present (Fig. 21). The true secondary wood is not shown really well in any longitudinal section ; so far as can be made out the pits on the radial walls of its elements are transversely elongated, so that there is here an approach to scalariform structure (Fig. 22, $x.^2$).

At some places remains of the cambium can be detected at the exterior of the secondary wood (Fig. 21, *cb.*). Beyond this we find in the furrows of the stele, groups of large thin-walled elements, recalling those in the phloëm of *Sphenophyllum insigne*[*] (Fig. 21, *ph.*). Longitudinal sections show that these elements were elongated, but no further details can be made out. There is, however, no reason to doubt that they represent a portion of the phloëm of the stele. There is a wide gap between stele and cortex, from which the remainder of the phloëm and anything there may have been of the nature of pericycle has perished. The width of the gap, however, appears to be partly due to shrinkage of the stele, the tissues of which show some signs of shrivelling.

The inner limit of the cortex is undulating, the bays corresponding to the angles of the stele, as in the axis of the cone.

The structure of the cortex is fairly uniform throughout its thickness, without any differentiation into distinct zones. It consists of short-celled parenchyma, in which large elongated elements, containing masses of dark carbonaceous substance, are scattered. In these respects there is a complete agreement with the structure of the axis of the cone.

We now come to an important point,—the course of the leaf-trace bundles.[†]

In the peduncle the leaf-trace bundles are not so well preserved as in the cone Sometimes we at first only recognise them by gaps in the tissues, but careful observation, as a rule, reveals the presence of tracheæ within or adjacent to these cavities (see Plate 3, photograph 18; Plate 6, figs. 26 and 27).

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[*] WILLIAMSON and SCOTT, "Further Observations," Part 1, Plate 84, figs. 51 and 52.

[†] *Cf.* WILLIAMSON, "Organization," Part 3, Plate 44, fig. 30, with photographs 4 and 5.

In some of the transverse sections (especially C.N. 540) we see the vascular bundles just leaving the stele, and here it is evident that a single strand starts from each angle, except when the angle is really a double one, in which case there are two outgoing strands. Very soon after entering the cortex, however, the outgoing leaf-trace divides; the division, where clearly shown, is triple, the three resulting bundles lying in the same tangential plane. The evidence, however, is not sufficient to prove that this triple division was constant. Probably it was fairly so, for at one place three triple bundles of the same whorl are seen side by side (C.N. 539).

From the comparison of the radial sections it is evident that an antero-posterior division of the trace also took place* (C.N. 543). The transverse sections rarely show this division, but in one place (Plate 5, fig. 17) it is quite clear. The group of bundles corresponds almost exactly to that shown from the axis of the cone in Plate 4, fig. 7. We see the three strands resulting from the first division, and the middle one of the three has just divided again to form an anterior and a posterior branch. So far, then, the course of the bundles in the WILLIAMSON specimen appears to agree exactly with that found in the axis of *Cheirostrobus*.

The bases of leaves or bracts are present, and the radial sections show that each of these appendages is bilobed, one lobe being superior or ventral, and the other inferior or dorsal (see Plate 6, figs. 24 and 25; also WILLIAMSON's fig. 30 above cited). The lobes were, no doubt, each sub-divided into segments in the horizontal plane (see Photograph 18, figs. 26 and 27; also WILLIAMSON's fig. 29), but only the stumps of these segments remain. The lower lobe appears to have been the broader, for at several places in the radial sections it is shown in its full extent, where the upper lobe is either missed altogether, or only partially shown (Figs. 24 and 25). The lower lobe was often, perhaps always, trifid, receiving the three anterior branches of the leaf-trace; the upper lobe appears to have been more frequently bifid, receiving two bundles only (see Photograph 18, and fig. 9), but sometimes this also received three bundles, as shown in Fig. 27. That this is really an upper lobe is shown by the fact that its bundles do not separate until quite near the periphery.

Owing to the paucity of the sections of the peduncle† and their frequent obscurity, it has not been possible to work out the course of the bundles with the same minuteness and certainty as in the axis of the cone. Enough, however, is shown to prove that their course and subdivisions follow the same general rules as in the axis, with the exception that one of the lobes (probably the upper) usually received two bundles instead of three.

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* Indicated in WILLIAMSON's figure, "Organization," Part 3, Plate 44, fig. 30.

† There are seven sections altogether, all in the WILLIAMSON collection. Four of these (C.N. 539–542) are transverse; two (C.N. 543 and 544) are approximately radial; and one (C.N. 545) tangential. The last mentioned is too obscure to throw much light on the course of the bundles; where it passes obliquely through the bases of the leaves, however, it shows that at least two bundles entered each lobe, perhaps three (see fig. 19).

The phyllotaxis of the specimen is not perfectly clear, but the arrangement of the leaf-bases, and more especially of the outgoing leaf-trace-bundles, as shown in the tangential section (Fig. 19), is strongly suggestive of superposed verticils. As we know that the number of orthostichies changed between one end of the fragment and the other, we cannot expect great regularity. The transverse sections are slightly oblique; allowing for this, the arrangement of the bundles and leaf-bases which they show is just what would result from a whorled phyllotaxis, and cannot be reconciled with any spiral system (see Fig. 19). That the whorls were superposed is further indicated by the fact that, in transverse sections, a protoxylem-angle, a leaf-trace, and a leaf all lie in the same radial line, where the arrangement is clearly shown.

We will now sum up the points of agreement between the peduncle and the axis of the cone. The chief points are as follows :—

1. The polyarch stele with prominent angles, at which the protoxylem is situated. In one section of the peduncle the actual number of angles (12) is identical with that in the cone.
2. The internal structure of the stele; the conjunctive tissue intermixed with tracheides; the multiseriate bordered pits on the tracheal walls.
3. The structure of the cortex, consisting of a uniform parenchyma, containing secretory (?) sacs.
4. The course of the leaf-trace bundles; the first division into three; the antero-posterior division of the middle bundle; the subdivision of its posterior branch.
5. The division of the leaf-base into a superior or ventral, and an inferior or dorsal lobe, the former receiving the posterior and the latter the anterior set of bundles resulting from the division of the trace.
6. The subdivision of each lobe into segments.
7. The arrangement of the appendages in superposed whorls.

The agreement is thus so close, and extends to so many points, as to leave no doubt that the WILLIAMSON fragment and the actual cone belonged to the same species, especially if we take into consideration their identical dimensions, and the fact that they occur in the same deposit.

In all probability the fragment is the peduncle of a cone. This is suggested by the exactness of the agreement in many points of structure and in dimensions, and especially by the fact that the leaf-bases of the fragment are so closely similar to the sporophyll-bases of the cone. Most probably they were bracts, or sterile sporophylls, rather than vegetative leaves.

An important fact remains which disposes of the only considerable difference in structure between the two specimens, and also raises the probability that the WILLIAMSON fragment is a peduncle almost to a certainty.

The section through the base of the cone (Plate 3, photograph 15) shows the upper part of the peduncle in connection with it. The wood of this part is shown in tangential section, and is evidently secondary wood, the plane of section missing the primary part. The tracheides agree in size and structure with those of the secondary wood in the WILLIAMSON specimen, while the more central primary tracheides are much larger both in peduncle and axis. The medullary rays are exceedingly evident, and can at once be distinguished from the primary conjunctive parenchyma shown in other sections (see Plate 5, fig. 16). Where the fertile sporophylls begin the secondary wood dies out, but the exact level at which it disappears cannot be determined, as the plane of section here passes outside the wood (Plate 3, photograph 18). In some cases the secondary tracheides show a delicate pitting on their tangential walls (Fig. 16, B). We thus see that the peduncle of the actual cone agrees in every respect, including secondary growth, with the WILLIAMSON fragment.

So far as can be judged, the secondary zone of the peduncle in connection with the cone is decidedly thicker than in the WILLIAMSON peduncle, so they cannot both have belonged to the same specimen. There is therefore a possibility that the strobilus belonging to the separate peduncle may still be found in the Pettycur material.

In the same preparation which shows the base of the cone there is contained an approximately radial section of what appears to be a branching stem. The secondary wood is well shown, and its histological structure agrees closely with that of the peduncle of *Cheirostrobus*, though in the doubtful fragment its development is much greater. The parenchymatous tissues are partly preserved, and contain structures much like the "secretory sacs" of our fossil. I think it not improbable that we have here a fragment of the vegetative organs of the plant to which the new cone belonged, but the specimen is in many respects obscure, and unless it should be possible to obtain additional preparations, no conclusion of value can be drawn from it.

SUMMARY.

1. *Cheirostrobus Pettycurensis* was a pedunculate cone of large size, consisting of an axis bearing numerous crowded verticils of compound sporophylls.
2. The sporophylls of successive verticils are superposed; the number in each verticil is twelve.
3. Each sporophyll is divided nearly to its base, into an upper (ventral or posterior) and a lower (dorsal or anterior) lobe; each lobe is deeply sub-divided in a palmate manner into segments, of which, as a rule, there are three to each lobe. In the sporophylls at the base of the cone, and in the bracts of the peduncle the number of segments is sometimes reduced.
4. Each segment consists of a long and slender horizontal stalk or petiolule bearing a lamina at its distal end.
5. Of the segments of each sporophyll half are fertile and half sterile. Most

probably it is the three upper segments in each case which are fertile, and the three lower which are sterile.

6. The lamina of a fertile segment or sporangiophore is thick and peltate, and bears the sporangia on its adaxial surface, as in *Calamostachys* or *Equisetum*.
7. The sporangia are of great length, extending back nearly or quite to the axis. Each sporangiophore bears as a rule four sporangia, and consequently there are usually twelve sporangia in all to each sporophyll.
8. The structure of the sporangial wall is identical with that of a *Calamostachys* or of *Sphenophyllum Dawsoni*.
9. The spores are uniform in size and structure in all parts of the specimen, including the sporangia at the base of the cone. Their average diameter is ·065 millim.
10. The laminæ of the sterile segments overlap those of the sporangiophores. The sterile lamina is of complex form, having two long upturned apices, and two shorter downward prolongations.
11. The petiolules and sporangia are closely packed together, and the surface of the cone completely invested by the fertile and sterile laminæ.
12. Axis and peduncle are traversed by a polyarch stele, with solid, centripetal primary wood. In the axis the number of xylem-angles is twelve, gradually sinking to nine in the peduncle.
13. A single leaf-trace bundle leaves each angle of the stele for each sporophyll. The leaf-trace subdivides in both planes on its way through the cortex, to supply the ventral and dorsal segments of the sporophyll.
14. In the peduncle, as distinguished from the axis, secondary tissues were formed by a normal cambium.

It may be well to repeat here the provisional generic and specific characters as given in the preliminary paper.

Cheirostrobus, gen. nov.

Cone consisting of a cylindrical axis, bearing numerous compound sporophylls, arranged in crowded many-membered verticils.

Sporophylls of successive verticils superposed.

Each sporophyll divided, nearly to its base, into an inferior and a superior lobe; lobes palmately sub-divided into long segments, of which some (probably the inferior) are sterile, and others (probably the superior) fertile, each segment consisting of an elongated stalk bearing a terminal lamina.

Laminæ of sterile segments foliaceous; those of fertile segments (or sporangiophores) peltate.

Sporangia, large, attached by their ends remote from the axis to the peltate laminæ of the sporangiophores.

Sporangia on each sporangiophore, usually four.

Spores very numerous in each sporangium.

Wood of axis polyarch.

C. Pettycurensis, sp. nov.

Cone, 3–4 centims. in diameter, seated on a distinct peduncle. Sporophylls, twelve in each verticil.

Each sporophyll usually sexpartite, three segments belonging to the inferior, and three to the superior lobe.

Sporangia densely crowded.

Spores about ·065 millim. in diameter.

Horizon: Calciferous Sandstone Series.

Locality: Pettycur, near Burntisland, Scotland. Found by Mr. James Bennie, of Edinburgh.

Affinities of Cheirostrobus.

The cone which has been described is an isolated specimen; apart from the peduncle, and the doubtful fragment of stem referred to on p. 19, we have not the slightest clue, as yet, to the nature of the vegetative organs of the plant which bore it. The one part which we possess, however—the fructification—is happily the most important from a taxonomic point of view; so, considering the perfection of its preservation, we may profitably enter on a discussion of the probable affinities of the fossil.

The first question which presents itself is this: was *Cheirostrobus* a Cryptogam or a Phanerogam? The latter alternative is not one to be rejected off-hand; the fructification might quite conceivably have been the male cone of a Gymnosperm. The remarkable morphology of the sporophylls, in fact, at once suggests a comparison with certain Coniferous strobili. The superior and inferior lobes of the sporophyll, especially if, as is almost certainly the case, the upper segments be the sporangiophores, may well be compared to the ovuliferous and carpellary scales of the Abietineæ. It is true that this would be to compare a male with a female strobilus; but it might be theoretically possible to suppose that an organization now limited to flowers of one sex might in early geological times have extended to those of the other also.

It is not, however, probable that this comparison amounts to anything more than a remote analogy. We can hardly compare an early Palæozoic fossil directly with a group, which, so far as we know, only makes its appearance well on in the Secondary period. The Gymnosperms known to us from the older rocks offer no definite points of analogy with *Cheirostrobus.**

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* RENAULT's figure of the male cone of *Cordaianthus Penjoni*, shown in longitudinal section ('Tiges de la Flore Carbonifère,' 1879, pl. 16, fig. 13), suggests at first sight a certain analogy with *Cheirostrobus*, but the resemblance is probably merely a superficial one.

The anatomical structure appears to negative the idea of Gymnospermous affinities. The polyarch centripetal wood is essentially a Lycopodiaceous character, and we have at present no evidence for the occurrence of this type of structure in any Gymnosperm, whether recent or fossil. It seems, therefore, that the alternative of Phanerogamic affinities must be eliminated, from want of evidence, and that the allies of *Cheirostrobus* must be sought among Vascular Cryptogams.

Cheirostrobus is a highly organized strobilus, more complex, perhaps, than that of any other Pteridophyte known to us, whether recent or fossil. We should therefore naturally look for its affinities among the strobiloid groups of Cryptogams, a limitation which would appear to exclude the Filicineæ from our consideration. It is not certain, however, that the possibility of Fern-relationship can be thus summarily dismissed. If we are justified in the belief that Filicineæ gave rise to Gymnosperms of the Cycadean type,* we must assume that at some stage or other, certain families of the Fern *phylum* acquired a cone-like fructification. In the female flower of *Cycas* we have still, perhaps, a reminiscence of such a transition. In the Pettycur deposit we have found in *Heterangium Grievii*, a plant which, according to its vegetative structure, shows a divergence from a Fern-type in a Cycadean direction. The idea crossed my mind whether there might not be something in common between *Cheirostrobus* and *Heterangium*. Certain points in the structure of the wood and cortex even seemed to suggest such a comparison, and the very complex form of the sporophylls in our cone was rather favourable to the idea of Fern-affinities. Such an hypothesis, however, had to be rejected almost as soon as formed; in particular, the superposed verticils of *Cheirostrobus* appeared fatal to it, and generally the sum of characters pointed too decidedly in other directions.

Cheirostrobus combines in a striking manner the characters of three of the main divisions of Pteridophytes: the Equisetineæ, the Lycopodineæ, and the Sphenophylleæ. With the Equisetineæ (taking the group in the wide sense, as co-extensive with the Calamarieæ of WEISS) there is the closest agreement in the organization of the sporangiophores and sporangia. The resemblance of the fertile segments of *Cheirostrobus* to the peltate scales of a *Calamostachys* or *Palæostachya* is most striking, extending even to such details as the distribution of the vascular bundles in the lamina.†

So, too, with the sporangia; in number, mode of attachment, and histological structure, they are absolutely identical with those of *Calamostachys*, and even their greatly elongated form can be paralleled from plants of that group.‡

* See WILLIAMSON and SCOTT, 'Further Observations,' Part III., p. 769. D. H. SCOTT, 'Address to Botanical Section of Brit. Association,' 1896, p. 16; also WARMING, 'Systematic Botany,' Engl. Ed., p. 252; SOLMS-LAUBACH, 'Bot. Zeitung,' 1893, p. 207. [The discovery by IKENO and HIRASE, of the multiciliate spermatozoids of *Cycas* and *Ginkgo* strikingly confirms this conclusion. June 25, 1897.]

† Compare especially WILLIAMSON, 'Organisation,' Part XV., pl. 2, fig. 8; RENAULT, 'Ann. des Sci. Nat.,' ser. 6, vol. 3, pl. 2, fig. 5, with our photographs 9–12, and fig. 12.

‡ As in *Calamodendrostachys Zeilleri*, RENAULT, 'Flore fossile d'Autun et d'Epinac,' Part II., Plate 60, figs. 3–8.

These points of agreement are far too numerous and exact to be passed over, and cannot readily be explained otherwise than by real affinity.

The resemblances to Lycopodineæ are limited to the anatomy, but, so far as they go, are striking enough. The general structure of the polyarch stele with centripetal wood is suggestive of a *Lepidodendron,* though the agreement does not extend to details. The principal differences consist in the straight vertical course of the protoxylem-angles, which do not form a network as in *Lepidodendron,* and in the pitted, as distinguished from scalariform tracheæ.* The anatomy of the central cylinder is, at any rate, sufficient to prove that we have not to do simply with a Calamarian cone.

It is with the Sphenophylleæ that the points of agreement are most numerous. They were briefly enumerated in the preliminary paper,† but it is necessary to recapitulate them somewhat more fully:—

1. The arrangement of the appendages in superposed verticils is a striking point of resemblance to *Sphenophyllum,* in which genus the fact of superposition is well established for the vegetative region, and indeed appears to be necessarily correlated with the anatomical structure.‡ Whether the superposition extended to the bracts of the strobilus in *Sphenophyllum* is somewhat doubtful. COUNT SOLMS-LAUBACH finds that this was the case in his *Bowmanites Römeri,* and thinks it may also have been so in the other fructifications of the family.§ The fact that the number of members in a whorl is a multiple of three (12 in the cone, diminishing to 9 in the peduncle) also recalls *Sphenophyllum,* though in *Cheirostrobus* these numbers do not bear the same relation to the anatomical structure as in that genus.

2. The palmatifid segmentation of the foliar appendages is a point in common with many species of *Sphenophyllum,* where every degree of such segmentation is found in many species, *e.g., S. tenerrimum, S. cuneifolium.*

3. The sub-division of the sporophyll into inferior and superior lobes, which are respectively sterile and fertile. As shown above, all the indications point to the superior segments being the fertile ones, though this could only be proved directly in a single case. Assuming that this is so, we have a remarkable agreement between *Cheirostrobus* and *Sphenophyllum Dawsoni,* or *cuneifolium,* in which the sporangiophores have the position of superior or ventral lobes of the bracts—a view of their nature which was taken by M. ZEILLER;‖ the comparison may, of course, be extended

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* The very prominent angles of the primary wood, giving it a stellate transverse section, are not usually so marked in the *Lepidodendreæ,* but can be paralleled in the axis of *Lepidostrobus Brownii.* See BOWER, 'Annals of Botany,' vol. 7, 1893, Plate 16, fig 3A.

† *Loc. cit.,* p. 423.

‡ SOLMS-LAUBACH, 'Fossil Botany,' Eng. Edit., p. 348; ZEILLER, 'Etude sur la constitution de l'appareil fructificateur des Sphénophyllum,' Mém. de la Soc. Géol. de France: 'Paléontologie,' Mém. 11; RENAULT, 'Cours de Bot. Fossile,' vol. 4 p. 29, 1885.

§ 'Bowmanites Römeri, eine neue Sphenophylleen-Fructification,' p. 242.

‖ *Loc. cit.,* p. 37.

to *Bowmanites Römeri* of COUNT SOLMS-LAUBACH. In *Cheirostrobus* the sterile and fertile segments are on so equal a footing that there can scarcely be a doubt as to the foliolar nature of the sporangiophores, and this, if our view of their position be correct, tends strongly to confirm M. ZEILLER'S interpretation in the case of *Sphenophyllum*. If, on the other hand, the evidence had pointed to the *lower* segments of the sporophyll in *Cheirostrobus* being the sporangiophores, we should then have had an analogy with *Cingularia*, a comparison which occurred to several botanists to whom I communicated my first observations. In *Cingularia*, according to the researches of WEISS, each whorl of sporangiophores is placed immediately below a whorl of sterile bracts, and in close contact with them. *Cingularia* agrees with our cone in having the members of the verticils superposed; in other respects, however, it is very different, notably in the form of the sporangiophores, which are not peltate, but strap-shaped, bearing the sporangia on their lower surface. I do not think it necessary to pursue the comparison further, until there is some better evidence for the relationship of this fossil to our cone. The affinities of *Cingularia* itself are likely to remain dubious, unless specimens with structure preserved should be found.*

4. The sporangiophores themselves, with the sporangia attached to a laminar enlargement at the distal end, are quite comparable to those of *Bowmanites Römeri*, SOLMS, in which each sporangiophore bears two sporangia.† The latter species, so far as this character is concerned, holds an intermediate position between *Sphenophyllum Dawsoni* and *Cheirostrobus*, which, in its turn, connects *B. Römeri* with *Palæostachya* and *Calamostachys*.

5. In the structure of the sporangia the agreement with Sphenophylleæ, and especially with *Sphenophyllum Dawsoni*, is as marked as with the Calamarian fructification.‡

6. The course of the leaf-trace bundles, their insertion on the prominent angles of the primary wood, and their repeated subdivision within the cortex, to supply the lobes and segments of the foliar organs, are strongly suggestive of *Sphenophyllum*. It was this character more than any other which led to the hypothesis of an affinity with *Sphenophyllum*, at a time when the peduncle only of *Cheirostrobus* was known to me.§ As regards the branching of the leaf-trace in one plane, *S. quadrifidum* and *S. Stephanense*, investigated by M. RENAULT, may be cited for comparison,|| while for the antero-posterior division we have a good analogy in the bundles supplying the bracts and sporangiophores of *S. Dawsoni*.¶

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* WEISS, 'Steinkohlen-Calamarien,' Heft 1, 1876, pp. 88–102, Plates 6–9; SOLMS-LAUBACH, 'Fossil Botany,' p. 334.

† *Cf.* SOLMS, *Bowmanites Römeri*, Plate 10, figs. 4 and 5.

‡ *Cf.* SOLMS, *loc. cit.*, p. 237.

§ 'Brit. Assoc. Report,' 1896, p. 1024.

|| 'Ann. des Sci. Nat., Bot.,' series 6, vol. 4, Plate 7; 'Cours de Bot. Fossile,' vol. 2, Plates 14 and 15.

¶ WILLIAMSON and SCOTT, 'Further Observations,' Part 1, p. 937, Plate 85, figs. 55 and 56.

7. The details of the structure of the vascular cylinder offer various points of resemblance to *Sphenophyllum.* The polyarch character is a difference, but not an insurmountable one. In some species of *Sphenophyllum, e.g., S. plurifoliatum* and *S. insigne*, the stele is simply triarch; in others, as *S. Dawsoni* and the French forms, it appears to be hexarch. In *Cheirostrobus* we have the numbers 9 and 12. The vertical course of the xylem-angles agrees with *Sphenophyllum* rather than with Lepidodendreæ; of the distribution of the secondary tissues in the peduncle the same may be said; the pitted tracheæ are quite similar to those of most species of *Sphenophyllum* of which the anatomy is known, though they differ from those of the contemporary *S. insigne.* In a word, the anatomy of the axis and peduncle is essentially that of a polyarch *Sphenophyllum.*

Taking all the characters collectively, it seems clear that *Cheirostrobus* has more in common with *Sphenophyllum* than with any other known group, recent or fossil, and that *Sphenophyllum* is thus no longer left perfectly isolated in the Vegetable Kingdom. At the same time, I do not consider the affinity between the two genera a very close one. If we regard the known Vascular Cryptogams as representing four main stocks or phyla—Filicineæ, Lycopodineæ, Equisetineæ, and Sphenophyllineæ, then we may fairly place *Cheirostrobus* in the last of the four series. Within the series Sphenophyllineæ, however, we must, I think, regard *Cheirostrobus* as the type of a new *family,* as distinct perhaps from that of *Sphenophyllum* as the Psiloteæ are from the Lycopodieæ.

As regards the question of heterospory, no profitable comparison can be drawn between *Cheirostrobus* and *Sphenophyllum,* for in neither case is the evidence by any means decisive. Our solitary specimen of the former shows only one kind of spore, and though it includes the base of the cone, where macrospores might, from analogy, be expected to occur, it is manifest that no conclusion can be drawn one way or the other from such slender evidence.

As regards *Sphenophyllum,* there is a fairly strong presumption that *S. Dawsoni,* the best-known fructification, was homosporous, for here a considerable number of specimens have been examined* without finding more than one kind of spore. In text-books, it is customary to assert positively that *Sphenophyllum* was heterosporous.† This assertion rests on M. RENAULT's interpretation of a single specimen, an interpretation which was always doubtful, and which he has now himself withdrawn.‡ It is true that M. RENAULT still inclines on other grounds to regard *Sphenophyllum* as heterosporous, but the remaining evidence is of an altogether indecisive character.

Having dealt with the relation of *Cheirostrobus* to *Sphenophyllum,* something remains to be said on the broader question of the relation of the Sphenophylleæ to other Vascular Cryptogams. That *Sphenophyllum* itself combines in certain respects Equisetaceous with Lycopodiaceous characters has long been recognized.[*] SCHENK and VAN TIEGHEM have dwelt more particularly on the points which it has in common with the latter—STUR, and more recently POTONIÉ, on those which it shares with the former. *Sphenophyllum* approaches the Equisetineæ in its whorled leaves and bracts, resembling *Bornia*, STERNB, in particular, in the superposition of the verticils, and in the sometimes forked leaves[†]; the fructifications also have something in common with those of Calamarieæ, the resemblance, so far as the sporangiophores are concerned, being most marked in the *Bowmanites Römeri* of SOLMS-LAUBACH.

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* WILLIAMSON and SCOTT, 'Further Observations,' Part 1, p. 939.

† See, for example, VAN TIEGHEM, 'Traité de Botanique,' 2nd ed., p. 1444; WARMING, 'Systematic Botany,' Engl. Ed., p. 233; SCHIMPER u. SCHENK, 'Palæophytologie,' p. 178; GOEBEL, 'Grundzüge der Systematik,' p. 216.

‡ 'Flore Fossile d'Autun et d'Epinac,' Part 2, 1896, p. 158.

The points in common between *Sphenophyllum* and Lycopodineæ are mainly anatomical—the centripetal primary wood being the chief resemblance. The agreement in vascular structure is most striking with the family Psiloteæ.

Curiously enough the resemblances *in both directions* are accentuated in *Cheirostrobus*. The marked Calamarian features have been sufficiently dwelt on above (p. 22). They are far too strong to be ignored. On the other hand, the structure of the stele is distinctly Lepidodendroid, in spite of the differences in detail already pointed out.

We may attempt to estimate the significance of these twofold resemblances as follows:—

Cheirostrobus is a more ancient form than the *Sphenophylleæ* with which we are best acquainted, for we know nothing as yet of the fructification of its contemporary, *S. insigne*. Yet it is highly complex, perhaps more so than any Calamarian, and certainly more so than any known Lycopod. As we have seen, it combines the characters of the two groups in a striking way. We may hazard the inference that *Cheirostrobus* as well as *Sphenophyllum* sprang from a very old stock, which existed prior to the divergence of the Lycopods and Calamarians. This common stock survived for a certain period side by side with these two divergent branches—between them, as it were. *Sphenophyllum* is a group which had advanced very far along this third line of descent, so that its common characters with the other lines have become comparatively obscure. *Cheirostrobus* has retained more of the common character, though reaching a high degree of complexity on its own lines.

This interpretation is of course highly hypothetical, but the fact stands firm that this early type of cone, while having much in common with *Sphenophyllum*, is at once more Calamarian and more Lycopodiaceous in character than that genus.

It must be remembered that in discussing the fructification of *Sphenophyllum* we are in some danger of generalizing from too few examples. The type of *S. Dawsoni*

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[*] See ZEILLER, "Bassin Houiller de Valenciennes—Flore Fossile," 1888, 'Texte,' p. 406.

[†] See POTONIÉ, "Die Beziehung der Sphenophyllaceen zu den Calamariaceen," 'Neues Jahrbuch für Mineralogie, &c.,' vol. 2, 1896, p. 141. The author lays special stress on the comparison with *Bornia*, for which *Asterocalamites*, SCHIMPER, and *Archæocalamites*, STUR, are synonyms.

and that of *Bowmanites Römeri* are fairly well known, but there can be no doubt that other forms of strobilus existed within the group. Thus, Mr. KIDSTON showed me a fructification of *S. majus* in his collection, in which the sporangia are distinctly grouped in fours. In *S. trichomatosum*, on the other hand, they appear to be single and axillary, though the possibility of a short pedicel having been present is not excluded. Evidently the range of variation within this so-called genus was very considerable. It is by no means certain that the simpler forms of fructification in *Sphenophyllum* were the more primitive. The analogy of *Cheirostrobus* rather points the other way, for here the sporangiophores are complex organs, bearing several sporangia, while at the same time they still show a marked similarity to the sterile segments of the sporophyll. Possibly we may regard the unisporangiate pedicels of *Sphenophyllum Dawsoni* as due to reduction, accompanied perhaps by chorisis, as there are two pedicels to each bract.

It is evident that the comparison with *Cheirostrobus* is likely to have a considerable influence on our views of the morphology of the Equisetineous strobilus; the apparent resemblance to *Palæostachya* has already been pointed out. This is a subject, however, which it would be premature to pursue further on the present occasion.

The fructifications of the typical Lycopodineæ, represented by *Lepidostrobus*, *Lycopodium*, and *Selaginella*, have little in common with those of the Sphenophyllineæ. On the other hand, the Psiloteæ deserve consideration from this point of view. It is not impossible that the synangium of *Psilotum* or *Tmesipteris* may represent a ventral sporangiophore with its sporangia, comparable to a fertile segment of the sporophyll in *Sphenophyllum* or *Cheirostrobus*. Such a conception appears to be quite consistent with the relative position of the parts, and with the course of the vascular bundles, and would tend to reconcile some at least of the divergent views which have been held as to the morphology of the Psilotaceous synangium.*

The Psiloteæ are undoubtedly highly modified plants, very remote from the ancient Sphenophyllineæ, but anatomically they have much in common with them, while they diverge very widely from the typical Lycopods.

The sub-division of the sporophyll in *Cheirostrobus* into fertile and sterile segments, of which, in all probability, the fertile are the superior in position, offers an obvious analogy with the Ophioglosseæ. A frond of *Ophioglossum palmatum* or some forms of *O. pendulum*,† for example, might be compared with a sporophyll of *Cheirostrobus*. I do not myself recognize anything more than an analogy here, but those authors who lay stress on the comparison of Ophioglosseæ with the Lycopods in general,‡ or with the Psiloteæ in particular,* may not improbably regard *Cheirostrobus* as affording support to their views. M. ZEILLER has already suggested on similar grounds the possibility of an affinity between *Sphenophyllum* and the Ophioglosseæ.†

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* *Cf.* F. O. BOWER, "Studies in the Morphology of Spore-producing Members—Equisetineæ and Lycopodineæ," 'Phil. Trans.,' B, vol. 185 (1894), p. 539.

† F. O. BOWER, 'Spore-producing Members,' Part II., 'Ophioglossaceæ,' 1896, Plates 8 and 9.

‡ F. O. BOWER, 'Ophioglossaceæ.'

To discuss these possibilities at length would carry us too far: the conclusion which I draw from the investigation of *Cheirostrobus*, is that this ancient form is most naturally placed in the same main division of Pteridophyta with *Sphenophyllum*, hitherto an isolated group. The characters of the new genus throw great light on those of its ally, and lead us to regard the Sphenophyllineæ as representing a generalized type, combining many of the features of Equisetineæ and Lycopodineæ, and indicating the common origin of these two series.

I cannot bring this memoir to a conclusion without again expressing my warm gratitude to my friend Mr. R. KIDSTON, to whom I owe my knowledge of the existence of his unique specimen, and the opportunity of investigating it.

The additional sections which I had prepared from the original block were cut for me by Mr. F. CHAPMAN.

The illustrations to this paper are partly photographic, the micro-photographs having been taken for me direct from the sections by Dr. E. C. BOUSFIELD. The other figures are from camera-lucida drawings by my assistant, Mr. W. C. WORSDELL.

The diagram on p. 7 was prepared for me by Mr. J. ALLEN, from a rough sketch by Mrs. D. H. SCOTT.

EXPLANATION OF PLATES 1–6.

Plates 1–3.—Photographs from the actual sections, taken by Dr. E. C. BOUSFIELD. Many require to be examined with a lens.

PLATE 1.

Photograph 1. Transverse section of the whole cone. In the middle is seen the axis, surrounded by the flattened mass of sporangia and sporophylls. *st.*, a sterile lamina, marking limit of specimen on the left; on the right the displaced sporangia, *sp.*, extend to the broken edge; *l.*, limit of specimen towards top of figure; *Lep.*, foreign body (Lepidodendroid cortex) limiting the specimen below. × 1½ diam. Slide K, 84A (see p. 2).

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* See SOLMS-LAUBACH, "Aufbau des Stockes von *Psilotum triquetrum*"; 'Ann. du Jard. Bot. de Buitenzorg,' vol. 4, p. 185, 1884.

† *Loc. cit.*, p. 37.

Photograph 2. Axis, enlarged, from same preparation. In the middle is the dodecarch stele. One complete whorl of twelve leaf-traces is shown, with parts of others. The successive divisions of the leaf-trace bundles can be followed. *l.t.*^{1}, trace just divided into three; *l.t.*^{2}, trace showing antero-posterior division of median bundle; *l.t.*^{3} (in outer whorl), same division more advanced; *s.b.*, sporophyll-bases; *s.b.*^{1}, shows the three posterior bundles entering the sporophyll. The spaces between the segments are packed with sporangia. × about 8 diam. Slide K, 84A (see pp. 3 and 10).

Photograph 3. Central part of axis, from another transverse section. *px.*, one of the twelve protoxylem-angles of the stele; *l.t.*, a leaf-trace bundle passing out from one of the angles; *l.t.*^{1}, another leaf-trace, which has already divided into three. Note that the tracheæ extend to the centre of the stele. × 24 diam. Slide S, 519 (see p. 9).

Photograph 4. Radial section of cone, showing axis, bearing sporophylls, with sporangia. *pet.*, one of the petiolules; *s.l.*, laminæ of the sporophyll-segments; *sp.*, the radially elongated sporangia. × 2½ diam. Slide K, 85 (see p. 4).

Photograph 5. Part of the same section, enlarged. *stele*, central cylinder of the axis. To the right several bases of sporophylls are shown, each dividing into an upper (*sup.*) and a lower (*inf.*) lobe. The antero-posterior division of the bundle supplying the lobes is also seen. *pet.*, one of the petiolules belonging to the superior lobe of a sporophyll; *sp.*, sporangia, packed between the sporophyll-bases and their segments. × about 8 diam. Slide K, 85 (see p. 4).

Photograph 6. Tangential section of cone, passing through the sporophyll-bases, *s.b.* Fourteen verticils are shown. Towards the bottom the sporophylls are seen breaking up into segments. *s.l.*, laminæ of sporophyll-segments, at periphery of cone. Between the laminæ and the leaf-bases the section passes through the petiolules and sporangia. × about 2 diam. Slide S, 528 (see pp. 3, 4 and 12).

PLATE 2.

Photograph 7. From the same tangential section as Photograph 6, enlarged, showing sporophyll-bases of six successive verticils. *s.b.*^{1}, sporophyll-base, showing the six bundles, three above and three below; it is coherent below with the adjacent sporophyll on the left; the two left-hand segments of the latter are seen separating, as the plane of section passes outwards. *s.b.*^{2}, sporophyll cut through at the level where the lower segments begin to separate; *s.b.*^{3}, separation of segments more advanced; *s.b.*^{4}, still more so. On either side petiolules intermixed with sporangia are seen. × about 8. Slide S, 528. (See pp. 4 and 12).

Photograph 8. Tangential section, passing through the cortex of axis, showing the leaf-trace bundles at various points of their outward course. The vertical series, *l.t.*, is in accurately tangential section, but the plane of section passes slightly outwards, from below upwards. Hence the bundles at the bottom of the figure are still undivided, while those further up are seen undergoing their successive divisions. The uppermost trace is in the same stage of division as that shown in Plate 4, fig. 8. Other leaf-traces and the bases of sporophylls are seen in oblique section. Outside the axis, the section passes through petiolules (*pet.*) and sporangia. × nearly 4 diam. Slide S, 520. (See p. 10).

Photograph 9. Radial section through the outer part of cone, showing the attachment of the sporangia to the peltate laminæ of the fertile segments or sporangiophores. *st.*[1], sterile segment (partly shown); *pet.*, its petiolule; *st.*[2]–*st.*[4], other sterile segments, alternating with the fertile segments, f^2–f^5; *sp.*, *sp.*, the two sporangia attached to the laminæ of the fertile segment f^3; f^4 shows the attachments of three sporangia. To the left are seen the apices of lower sterile laminæ. × about 10. Slide S, 521. (See pp. 4 and 12).

Photograph 10. Similar section to last, showing better the alternation of sterile (*st.*[1]–*st.*[3]) and fertile (f^1–f^4) laminæ. At *st.*[3], the form of the sterile lamina is well shown. The insertion of the sporangia on the fertile laminæ is also shown. × about 10. Slide K, 87. (See pp. 5 and 12).

Photograph 11. Another radial section, showing the form of a sterile lamina (*st.*, *st.*) specially well. Note the stout downward protrusion, overlapping the fertile lamina *f*, and the thinner upturned apex, both of which are double, as shown in Photograph 12. *a.*, attachment of one of the sporangia to a fertile lamina. × about 12. Slide K, 87. (See p. 5).

Photograph 12. Transverse section from the periphery of the cone, passing medianly through two fertile laminæ, *f.*[1] and *f.*[2], showing their sporangia. *st.*, the two downward protrusions belonging to the sterile lamina next *above* *f.*[1]; *st.*[1], the two apical outgrowths belonging to the sterile laminæ next *below* *f.*[1] (*cf.* Photographs 10 and 11). × about 16. Slide K, 84B (see pp. 4 and 5).

PLATE 3.

Photograph 13. Similar transverse section to Photograph 12, but passing medianly through the *sterile* laminæ, *st.* The apices of others are shown in transverse section. *f.*, *f.*, the two lateral lobes of a fertile lamina; through the groove between them the sterile segment passes out. The insertion of the sporangia is clear (*cf.* Photograph 11). × about 16. Slide S, 519 (see pp. 4 and 5).

Photograph 14. Tangential section across the petiolules (*pet.*), the vertical series of which are evident. *l.*, *l.*, laminæ at the periphery, cut obliquely. Note the closely-packed sporangia, twice as numerous as the petiolules, and therefore four times as numerous as those of the fertile segments. × 3½. Slide S, 525 (see p. 4).

Photograph 15. Approximately radial section from the base of the cone. The section becomes decidedly tangential towards the top and right-hand side. *l.*, laminæ at periphery. *s. inf.*, inferior segment of a sporophyll, the only one which can be traced through its whole length (*cf.* Plate 5, fig. 15A). $x.^2$, secondary wood of peduncle (*cf.* Plate 5, fig. 16). × about 3. Slide K, 88A (see p. 8).

Photograph 16. Spores from middle part of cone. × about 110 (see p. 14).

Photograph 17. Tracheides from interior of primary wood, to show bordered pits, *b.p.* × about 200. Slide K, 85 (see p. 9).

Photograph 18. Transverse section of peduncle (WILLIAMSON specimen). *stele*, central cylinder, with nine xylem-angles. *l.t.*, leaf-trace before dividing; $l.t.^1$, $l.t.^1$, forking bundles, derived from division of leaf-trace. *Het.*, foreign body (*Heterangium* cortex). × about 8 (see p. 15). C.N. 541.

Plates 4–6.—Figures from camera-lucida drawings by Mr. W. C. WORSDELL.

PLATE 4.

Fig. 1. Part of an approximately radial section, passing through an angle of the wood. *px.*, disorganized spiral or annular tracheides of the protoxylem; $x.^1$, more densely spiral tracheides at the extreme angle; *x.*, tracheides of the more internal wood. × 390. Slide S, 521 (see p. 9).

Fig. 2. Pitted tracheide from the interior of the wood, shown in a radial section. The outline of an adjacent thin-walled element is shown. × 200. Slide K, 85 (see p. 9).

Fig. 3. Short reticulate tracheide from the interior of the wood, seated on another, trumpet-shaped, tracheide. × 200. Slide K, 85 (see p. 9).

Fig. 3A. Three tracheides from the interior of the wood, seen in transverse section, showing the reticulate transverse walls. × 200. Slide S, 519 (see p. 9).

Fig. 4. Part of a transverse section, showing one of the angles of the wood and a portion of the inner cortex. *px.*, protoxylem-group; *l.t.*, leaf-trace bundle passing out from the angle of the stele; *ss.*, *ss.*, "secretory sacs" in the inner cortical tissue (*cf.* Photograph 3). × 85. Slide K, 84A (see pp. 10 and 11).

Fig. 5. Part of the inner cortex, in radial section. *ss.*, *ss.*, "secretory sacs," imbedded in the cortical parenchyma. × 85. Slide K, 85 (see p. 11).

Fig. 6. Group of three bundles, resulting from the first division of a leaf-trace, seen in transverse section, from the middle part of the cortex. The lower side of the figure is towards the exterior of the axis. *med.*, median bundle;

x., its xylem; *ph.*, its phloëm; chiefly preserved on the outer side; *lat.*, *lat.*, the two lateral bundles of the trace (*cf.* Photograph 2, *l.t.*[1]). × 130. Slide S, 519 (see p. 10).

Fig. 7. Group of four bundles, resulting from the first and second divisions of a leaf-trace, seen in transverse section, from the outer part of the cortex. *ant.*, anterior median bundle; *post.*, posterior do. do.; the posterior bundle is beginning to divide further. *lat.*, *lat.*, the two lateral bundles of the trace; *ep.*, epidermis of axis (*cf.* Photograph 2, *l.t.*[3]). × 35. Slide S, 519 (see p. 10).

Fig. 8. Group of four bundles, resulting from the first and second divisions of a leaf-trace, seen in tangential section of the cortex. *ant.*, anterior median bundle; *post.*, posterior do., do.; *lat.*, *lat.*, the two lateral bundles of the trace. × 57. Slide K, 86 (*cf.* Photograph 8), (see p. 10).

Fig. 9. Antero-posterior division of the median bundle of a leaf-trace, seen in radial section of the cortex. *ant.*, anterior bundle; *post.*, posterior bundle. They unite below. × 85. Slide K, 85 (*cf.* Photograph 5), (see p. 10).

PLATE 5.

Fig. 10. One of the upper or posterior bundles in the base of a sporophyll, seen in transverse section, *i.e.*, in tangential section of the whole cone. *x.*, xylem of bundle, with the smallest elements towards the centre; *ph.*, phloëm, surrounding the xylem; *pc.*, pericyclic or peridesmic tissue. × 390. Slide S, 528 (*cf.* Photograph 7), (see p. 12).

Fig. 11. Similar section of one of the lower, or anterior bundles. Lettering as before. × 390. Slide S, 522 (see p. 12).

Fig. 12. Peltate laminæ of sporangiophores, showing the attachment of the sporangia, seen in approximately radial section. The whole of one lamina is shown, with insertions of two sporangia, and half the next with the insertion of one of its sporangia; *v.b.*, *v.b.*, two vascular bundles of the lamina, diverging from the main bundle in the pedicel *ped.*; *v.b.*[1], ultimate branch of the bundle in the other lamina, passing to the base of a sporangium. × 30. Slide S, 522 (*cf.* Photographs 9–11), (see pp. 4 and 12).

Fig. 13. Structure of sporangial wall. A, in surface view, showing the "buttresses" jutting out from the radial cell-walls. B, in radial section, showing the edges of the "buttresses." C, in tangential section, showing the "buttresses" in their full width. The upper surface is towards the sporangial cavity. × 130. A and B, slide K, 85; C, slide S, 528 (see p. 13).

Fig. 14. Three spores, from the middle part of the cone, showing the ridges on their membrane (*cf.* fig. 15B). × 130. Slide S, 521 (see p. 14).

Fig. 15. A. Part of an approximately radial section of the base of the cone, showing

basal sporophylls, and sporangia. *sup.*, one of the superior segments of a sporophyll; *inf.*, inferior segment of the same sporophyll, seen in its full extent. It is to all appearance sterile; *a*, attachment of a sporangium to a fertile segment of the next sporophyll below; *ax-ax*, cortex of axis; *v.b.*, *v.b.*, vascular bundles on their way to the sporophyll. × $12\frac{1}{2}$ (*cf.* photograph). Note that the fractures in the sporophyll shown in the photograph are here filled up; in all other respects the figure is exact. (see p. 8). B. Spores from one of the basal sporangia. × 130. Slide K, 88A (*cf.* fig. 14) (see p. 14).

Fig. 16. A. Part of the secondary wood from the base of the axis of the cone, seen in tangential section. *tr.*, tracheides; *r.*, medullary rays. × 85. B. Part of a tracheide enlarged, to show the delicate tangential pits. × 200. Slide K, 88A (*cf.* photograph 15) (see p. 19).

Fig. 17. Part of a transverse section through the cortex of the peduncle (WILLIAMSON specimen), to show a group of bundles resulting from the division of a leaf-trace. The left-hand side corresponds to the exterior of the cortex. *ant.*, anterior; *post.*, posterior, branch of the median bundle; *lat.*, *lat.*, the two lateral bundles of the trace (*cf.* fig. 7). The parenchyma is somewhat diagrammatic. × 30. C.N. 540* (see p. 17).

PLATE 6.

(*All these figures are from the* WILLIAMSON *specimen*).

Fig. 18. Transverse section of the peduncle. *st.*, stele; *l.t.*, leaf-trace bundles passing through the cortex; L, L, bases of leaves; that to the right is evidently bilobed, and is entered by two vascular bundles converging towards the interior. × 4. C.N. 540 (see p. 15).

Fig. 19. Tangential section through the cortex of the peduncle. *l.t.*, leaf-trace bundles, some of which occur in pairs; L, L, bases of leaves; one to the right shows four vascular bundles. × 4. C.N. 545 (see p. 17).

Fig. 20. Transverse section of the stele, which at this level shows nine prominent angles. *px.*, one of the groups of protoxylem; there is one such group in most of the angles, but probably two in that to the right; x^2, secondary wood, distinguished by its radially-arranged elements; *ph.*, one of the phloëm-groups, which are situated in the bays between the prominences. The whole interior is occupied by tracheæ, intermixed with thin-walled cells. × 30. C.N. 541 (see p. 15).

Fig. 21. One of the prominences of the stele, enlarged. *px.*, group of protoxylem at the angle; *x*, part of the primary wood; x^2, secondary wood, consisting

of radial series of tracheæ, separated by medullary rays (*r.*); *ph.*, *ph.*, two of the phloëm-groups; *cb.*, remains of cambium. × 175. C.N. 541 (see p. 16).

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* "C.N." indicates *Cabinet number* in the WILLIAMSON Collection.

Fig. 22. Part of a radial longitudinal section passing through one of the angles of the stele. The exterior is towards the right. *px.*, protoxylem-group, consisting of spiral tracheæ; $x.^2$, probably secondary wood; the pitting is obscure; *x.*, large tracheide of the primary wood, with numerous bordered pits × 200. C.N. 544 (see p. 15).

Fig. 23. From another part of the same section, showing a portion of the interior of the primary wood. *tr.*, *tr.*, tracheides, one of which shows two rows of very distinct bordered pits; *c.p.*, conjunctive parenchyma. × 300. C.N. 544 (see p. 16).

Fig. 24. From a radial section of the peduncle, showing the base of a leaf, which is distinctly bilobed. *v.l.*, upper or ventral lobe; *d.l.*, lower or dorsal lobe; *f.b.*, *f.b.*, vascular bundles passing into the two lobes. × 15. C.N. 543 (see p. 17).

Fig. 25. Another leaf-base, in radial section. *v.l.*, ventral lobe, here almost disappearing; *d.l.*, dorsal lobe; *f.b.*, vascular bundle. × 15. C.N. 544 (see p. 17).

Fig. 26. Part of the same transverse section from which figs. 20 and 21 are taken, to show the cortex. L, L, bases of two leaves; *f.b.*, *f.b.*, the foliar vascular bundles, showing tracheæ. The two bundles which enter each leaf form a V, meeting towards the interior. The dark cells in the cortex may be secretory sacs. Part of the stele is shown. *px.*, *px.*, protoxylem-groups; *ph.*, phloëm. × 30. C.N. 541 (see p. 17).

Fig. 27. Part of another transverse section, showing the base of a leaf, which here has three lobes. *f.b.*, the three vascular bundles entering the leaf, and all converging towards the interior. The dotted lines to either side indicate the contour of the cortex. × 45. C.N. 539 (see p. 17).

II. *Studies in the Morphology of Spore-Producing Members.—III. Marattiaceæ.*[*]

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[PLATES 7–11.]

INTRODUCTION.

IN the two Memoirs of this Series already published, I have dealt with the spore-bearing members of the Equisetineæ, of the Lycopodineæ (including Psilotaceæ and Isoeteæ), and of the Ophioglossaceæ. We must now take up the case of the remaining class of Pteridophyta, viz., the Filicineæ. Of the two sub-classes into which it is divided, I propose to leave the Hydropterideæ for the present on one side, and discuss first the sub-class of homosporous Ferns.

In a previous paper ('Annals of Botany,' vol. 5, p. 109), I have advanced what appear to me to be good reasons for the opinion that the Eusporangiate Ferns represent a more primitive type than the Leptosporangiate. Accordingly, I propose first to take into our detailed consideration the sori of the Marattiaceæ, and it is to them that the present Memoir will be devoted.

I shall assume that those who are interested in this subject will have already made themselves acquainted with the general theoretical position which has been disclosed in the two earlier Memoirs of this series, and I shall not, therefore, recapitulate my views here. But in stating in detail the facts relating to the Marattiaceous sorus, I shall endeavour so to state them as to avoid theory, and reserve the theoretical treatment for separate sections of the text, apart from those which are descriptive.

DANÆA.

Though various writers have contributed to our knowledge of the development of the sori in other genera of the Marattiaceæ, *Danæa* has been left almost untouched: doubtless, this is mainly due to the difficulty of securing suitable material; but it is strange that these difficulties have not sooner been overcome, for on grounds of general comparison it would appear to be an important form. The mature condition, however, has been repeatedly described; and the general characters of the genus are well known.* I do not propose to discuss the vegetative organs, but merely note that in *D. simplicifolia* (RUDGE), the leaf is simple, and of ovate-lanceolate outline; in other species, however, it is simply pinnate. The fertile leaves resemble the sterile in outline, but are of smaller area, while the greater part of their lower surface is occupied by the large cake-like sori, which lie parallel to one another, and follow the course of the straight nerves from the enlarged midrib towards the margin. In various species it has been noted that the leaf may be only partially fertile, and in these the regular uniformity of outline of the sorus may be departed from, as it is also occasionally in the normal fertile leaf. The sori may be found to be abstricted (Plate 7, fig. 1, *a.*, arrow), and the single sorus may be divided into two or more parts in a somewhat irregular fashion (fig. 1, *b.c.*). This has been noted in various species. The resulting sori are frequently of circular outline, having a single series of sporangia disposed in a ring round a central point. This is virtually identical with the arrangement of the sporangia in the sorus of *Kaulfussia æsculifolia* (BLUME).

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[*] Part I. of these Studies appeared in 'Phil. Trans.,' B, 1894, pp. 473–572 (Plates 42–52): of Part II. only an Abstract was published by the Society (see 'Roy. Soc. Proceedings,' vol. 59, p. 137); the full paper was published independently by the Author (DULAU & Co., London), 1896.

The details of structure of the sorus have been represented by KUNZE (*loc. cit.*, Tab. 28) for *D. stenophylla* (KUNZE), and by MARTIUS (*loc. cit.*, vol. 11). More elaborate drawings, though perhaps less correct in detail, are those of FRANCIS BAUER, in HOOKER's 'Genera Filicum,' vol. 7; the description of them is, however, obscured by the peculiar use of the term "indusium." But the best drawings are those of GREVILLE (HOOKER and GREVILLE, 'Icones Filicum,' vol. 1, p. 18) of *D. alata*, which represent correctly the main points of structure of the mature sorus. From these sources it is apparent that the sorus consists of two rows of confluent sporangia, the loculi of which are separated from one another by complete septa, while they dehisce by distinct pores upon the outer, free surface. Each sorus is inserted above a single nerve, and between the sori, plates of tissue arise from the surface of the leaf; these plates, which have been described as indusia, are enlarged upwards so as partially to cover the sori (compare 'Genera Filicum,' Tab. 7, figs. 2, 4, 6). With insufficient data such as these before us, and without any facts of development, we must begin the investigation of the sori of *Danæa.*

The material used was of *D. elliptica* (SMITH), collected by Mr. ELLIOT, in St. Vincent, and forwarded to me through Mr. GEORGE MURRAY, and *D. alata* (SMITH), sent to me by the late Dr. TRIMEN. The characters of these species are well known; the sori were found to be essentially similar in the two species, except that the number of loculi in *D. alata* is much smaller than in *D. elliptica.* If the sporophyll of the latter species be cut so as to traverse the sori transversely, the outline appears as in fig. 2, in which are seen inserted on part of the expanded lamina three indusia (*i.*), and alternating with them two sori (*s.*), the latter being seated above respective vascular bundles (*v.b.*). It will be noted how large are the indusia, and how they partially overarch the margins of the sori. The latter each show two loculi, or sporangia, limited by a wall, which consists in the mature state of several layers of cells, of which the outermost is considerably thickened; the sorus to the right has been so cut as to traverse the pores of dehiscence, which are thus seen to lie close to the septum. If sections be cut parallel to the surface of the leaf, so as to traverse the sori, they appear as in fig. 3; three sori are there seen closely fitted round by the indusia. It will be noted that the loculi vary in size, arrangement, and form, those at the end of the sorus deviating far from the ordinary roughly rectangular outline. Lastly, if a section be cut, so as to traverse the length of the sorus, it would appear as in fig. 4, in which the vascular bundle runs below its whole length, while the indusium (*i.*) overlaps the ends in very much the same way as the velum, or indusium of *Isoetes;* in part the section has traversed the pores of dehiscence, but in part of it the loculi appear closed. While we thus recognise the main features of the sorus, it should be at once noted that deviations of detail are frequent; the most noteworthy is the occurrence of incomplete septa (fig. 5), which appear not uncommonly as flanges of tissue running partway across the cavity of a sporangium; they are sometimes found, as in our illustration, running from the outer wall inwards; sometimes they are attached to the sides of the loculus. These incomplete flanges may be compared structurally with those in the sporangium of *Isoetes* (compare 'Phil. Trans.,' B, 1894, fig. 116, *x*), where, instead of free trabeculæ, the sterile tissue projects from the lateral wall as a partial septum into the sporangial cavity.

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* HOOKER, 'Synopsis Filicum,' p. 442; MARTIUS, 'Flora Brasiliensis,' Fascic. 23, p. 154; HOOKER, 'Gen. Filic.,' Tab. 7; PRESL, 'Suppl. Tent. Pterid.,' p. 33; KUNZE, 'Farrnkräuter,' pp. 55 and 107, &c., &c.

From these drawings a general idea of the structure of the sorus may be derived. The next step will be to give such details of its development as the material at disposal would allow. It is to be regretted that I have not been able to observe the earliest stages, but as the essential features are found to be very similar to those of *Marattia* and *Kaulfussia,* this is not, perhaps, of so great moment. We will at first discuss the development of normal sporangia, leaving on one side, for the present, those abnormal cases above noted, which have, however, a very special interest.

The earliest condition of the sorus which I have observed is such as is shown in fig. 6, which traverses the sorus vertically, and follows its longer axis; here the sporogenous groups are already of considerable size, while their arrangement is such that, as regards their origin, they are readily referable, together with the superficial cells which cover them, to a single parent cell. This may be called the superficial parent cell; it was doubtless of deep oblong form, with its longer axis perpendicular to the surface, and one of its ends flush with the outer surface. It is, however, impossible to decide from stages so late as this, what the actual succession of segmentations in this parent cell has been, and whether the archesporium is or is not defined finally by the first periclinal wall in the original parent cell. A point, which is of some interest is the very considerable variety of bulk of the sporogenous groups of successive loculi; this is obvious in fig. 6, which represents three sporangia taken at random. No two of these show the same details of segmentation; the most prominent difference is in their width; the depth of them, however, and the thickness of the tissue which will form the outer wall is almost constant. In figs. 7, *a*, *b*, *c*, other cases are shown for comparison; in *c*, the sporogenous group appears only about one-half the size of that in *a*; these differences of bulk have an important bearing, which will be explained below. Though, in the large majority of cases, the sporogenous group, together with the cells of the wall covering it, are thus referable to a single parent cell, examples are to be seen where this cannot be recognised. A case of this is shown in fig. 8, in which it would seem probable that two original parent cells in juxtaposition have been involved. With this should be compared the very regular sporangium in fig. 9, which may be taken as representing the normal type in the same leaf from which fig. 8 was taken. I am not able to state positively that the sporogenous tissue in these sporangia does originate from two parent cells, but, if that be so, as seems probable, in each case it is only a part of the product of such cells which has gone to form the sporogenous mass, the rest contributes to the tissue of tapetum and septum. These considerations will also be found to have an interest in connection with the theory of the sorus.

A transverse section through part of a sorus of the same age as fig. 6 is represented in fig. 10; and again the variation of detail is seen, the form, bulk, and mode of segmentation of neighbouring sporangia not conforming to any strict plan. Again, in fig. 11, extreme cases of difference of the sporogenous groups, all from the same leaf, have been traced in outline, and it will thus be noted that the number of cells of the sporogenous group traversed by the plane of section may vary from 4 to 16, in sporangia of the same age; this is a very considerable margin of difference, which, I think, it would be difficult to match in any other genus of *Pteridophyta*.

Sections, transverse to the axis of the sorus and vertically through the pinna at this stage, appear as fig. 12; here the indusium is seen, as before in fig. 2, overarching the sporangium as a close investment. The sporogenous group, which is shaded, is clearly referable in origin to a single parent cell, together with the region of wall which immediately covers it. It will be readily understood from what has already been said of the variation of detail as seen in other sections, that here also the arrangement and number of the cells is liable to vary, and the fig. 12 must be understood to represent an average sporangium, which shows a segmentation of greater regularity than can always be counted on.

Putting together now the results derived from sections in the three directions described, an idea will be obtained of the sporangium as a solid body. If a section were cut through the sporangium in fig. 12 in a direction X, X, it would correspond, as regards number of cells, with the middle sporangium in fig. 6; while a section along the line Y, Y, would correspond in all essential points with the left-hand sporangium in fig. 10. These may be considered as normal and regular sporangia. We conclude, therefore, that in an average case the origin of the sporogenous group is, as has been described, by segmentation of a single superficial cell, to be called the superficial parent cell, and that, at the age described, the sporogenous group is a flattened plate of tissue consisting of about 44 cells. This is, however, only an average case, and all the dimensions are subject to variation of detail. The form and segmentation in the sporangia which lie at the end of the sorus depart far from the type thus described; this might have been anticipated from their mature form (fig. 3), and it is illustrated in the outline of the sporogenous group, fig. 11, as well as by fig. 13, which represents the end of a sorus of *D. elliptica.*

As development proceeds, and the sporogenous group undergoes segmentation, it becomes naturally more difficult to trace the genetic relationships of the walls. The cells lying immediately outside the sporogenous tissue now enlarge, sometimes undergoing division, their contents become poor and transparent, and they assume the characters of a tapetum (*x*, figs. 8, 9, 14, 15); at the same time, while the inner limit of the tapetum becomes less regular, owing to the frequent enlargement of some of its cells so as to encroach on the sporogenous group, the outer limit commonly becomes more regular; the result is that the outer limit assumes the appearance of the natural boundary of the loculus; but, notwithstanding this appearance, it must be remembered that the tapetum is not derived from the sporogenous group, but from the tissue surrounding it. Meanwhile, additional divisions will have taken place in the cells which form the wall of the sorus, and these, though irregular, result in some three layers of cells in the lateral region (figs. 14, 15); at the apex of the sporangium, however, it is thicker, as is seen in fig. 14, and also in figs. 8 and 9, which traverse the region where the dehiscence takes place. As regards the division of the spore-mother-cells to form tetrads, and the maturing of the spores, I have nothing of importance to add, as apart from what is known in other Marattiaceæ.

The dehiscence of the sporangia demands a special description; it is well known to be by pores, which are represented in all the old figures; Sir WILLIAM HOOKER, in the letterpress appended to his Plate 7, of the 'Genera Filicum,' describes each pore as "communicating with a number of transverse chambers or cells, and each chamber having two (for there does not appear to be a dissepiment between them) sporangia." This description must have been based on some misconception, for each pore, as a rule, leads into one loculus only.

The wall of the sporangium at maturity consists of a superficial layer of cells with slightly thickened walls, while the subjacent cells remain thin-walled, and are liable to collapse when fully ripe (fig. 18), so that, in parts at least, the wall of the mature sporangium may consist of a single layer of cells. The mechanism of dehiscence is exceedingly simple: as ripeness approaches, certain cells of the thickened outer layer, situated where the pore will be formed, may be distinguished by their smaller size, both in surface view (fig. 16), and also in section (fig. 17): the thinner-walled cells below begin to shrivel (fig. 18), forming thus an extension of the cavity of the loculus upwards towards the surface; as this is approached, the smaller cells above noted come apart (fig. 18), and as they themselves also shrivel, the result is a slit-like pore, which assumes an irregular oval outline, being lined by the persistent remains of the shrivelled cells (fig. 19). The actual rupture is thus seen to occur in the cells immediately above the sporogenous group: these it will be remembered, appear to have a common origin with the sporogenous group from an original parent cell. It will be further noted that there is nothing here of the nature of an annulus; there are no specially indurated, or hygroscopic cells, not even such as are found in *Angiopteris.* In fact, with the exception of those plants in which the shedding of the spores takes place in water, this mode of dehiscence is probably the simplest of any Filicineæ. And yet, as will be subsequently pointed out, it is fundamentally the same type as holds for all other Marattiaceæ.

From the sections above described of sporangia just before the rounding off and tetrad division, it is possible to estimate the approximate number of spore-mother-cells; and multiplying the number of these by four, the potential number of spores of each sporangium may be arrived at: but in making estimates it is to be remembered how variable the sporangia are in this genus. In an average example of *D. alata* (fig. 14) there are 108 spore-mother-cells exposed in the single vertical section; fig. 15 shows that there are about 4 layers of them: the total number of spore-mother-cells is therefore about 432, and the potential output of spores will be about 1728 for an average sporangium.

Abnormalities.

Having considered the normal sporangium, and traced its development as far as the material at hand would allow, we may turn to the abnormalities, which here present matter of considerable importance. In certain cases the sporangia though varying in size and form, do so within reasonable limits (figs. 3, 4), and frequently whole sori may be found in which there is no case of marked anomaly. In other cases, however, the anomalies are numerous, so much so that it would be difficult to find three or four successive loculi at all nearly similar to one another (fig. 20). Examining the details of outline of the loculi in fig. 20, it will be seen that they vary very greatly in size, some being narrow and compressed, others being elongated in the direction of the longer axis of the sorus; the largest of these (x), show slight lateral extensions of the sterile tissue into the sporogenous mass, these appearing as partial septa: in other cases the septum may be complete, dividing the loculus into two, while it is common to note two equal sporangia side by side, which thus illustrate a complete septation by means of a broader wall. It will be necessary, in view of the theoretical interest which attaches to the question of septation, to look more closely into the details of these extraordinary abnormalities, but I shall endeavour first to give a plain statement of the facts, without reference to opinions which may be based upon them.

It is at the period when the difference in character of the tapetal and sporogenous cells becomes clearly marked, both by form and contents, that these anomalies, of which in early stages it is difficult to be sure, may be studied with some degree of certainty. The sporogenous tissue does not appear to be always strictly limited to so regular groups of cells as those previously described: thus in fig. 21, a packet of cells, evidently the result of subdivision of one, projects beyond the neighbouring group, though it shares their characters; this case, which is uncommon, was verified by comparing the whole series of microtome sections through that loculus, and there is no doubt of the fact. We may compare this with what has been described in *Isoetes* in a former Memoir ('Phil. Trans.' B, 1894 p. 531, figs. 106–108), and occasionally in some other plants. A much more common irregularity is the converse: viz., that certain cells, often clearly sister-cells with those of the sporogenous group, remain sterile, and develop as tapetum, or it may be as permanent tissue of a septum. Examples of this are seen in figs. 22, 23, in which the cells (*st*) are clearly sister-cells with those of the sporogenous group, though they develop differently, showing already by the cessation of division, and by the poverty of their protoplasm, that they will be sterile; there is thus a partial sterilisation of the sporogenous group in certain cases.

Another feature, not to be confused with this, though producing similar results, is the encroachment of some of the tapetal cells upon the sporogenous mass; this is well shown in fig. 24, and it is specially a feature in loculi which are larger than the normal; it would appear as though this were a means of enlarging the absorptive surface of the sporogenous group, and leading the nutritive supply into the mass of it. It will be noted how, in fig. 24, many of the tapetal cells (x) become convex, and project as rounded sacs inwards, which may even at times undergo division into two or more cells.

Though in such cases as those quoted (figs. 22–24) these two modes of origin of sterile cells in close connection with the sporogenous cells may be distinguished with some degree of certainty, this is not always so, and it is frequently a matter of difficulty to decide of which nature the sterile cells may be which are seen; for instance, in the loculi represented in Plate 8 fig. 25, *a*, *b*, *c*, *d*, the origin of the cells marked (?) is doubtful, whether by ingrowth of tapetum or by sterilisation of cells of the sporogenous groups; the latter interpretation, however, appears in some cases to be the more probable. But whatever their origin, the presence of such sterile cells among the sporogenous cells is not an uncommon factor.

Having thus recognised the two sources of sterile cells, we may now consider them in their relation to the septation of loculi. As already noted, it is in the larger loculi that sterile cells are most commonly found (fig. 20), and that various conditions of partial septation are seen in them. Thus, in fig. 24, in a loculus which is slightly above the average size, processes are seen opposite to one another, which suggest a median constriction of the large loculus; that is an approach to a condition of septation. This is, however, more pronounced in the much larger loculus shown in fig. 26, in which not only is there a median constriction, but also the cells marked (?), evidently sister-cells with the sporogenous groups, show intermediate characters between tapetum and sporogenous cells. From their position, if sterile and developed as permanent tissue, these would complete the septum; but their cell walls do not show that firmness which is already characteristic of the tissue of the sporangial wall, or of normal septa; probably in such cases the cells we are discussing become disorganised as the loculus approaches maturity. A further example, and a more complex one, is shown in fig. 27, which represents the large, partially trilocular specimen seen in the middle sorus of fig. 20; here the state of things is much the same as in fig. 26, the septa being incomplete, and probably only transitory, while the cells marked (?) show only a slight deviation from the normal. It is noteworthy that a triple partial septation, such as this, may occur; examples of it are not common, but the loculus here figured is not the only one of the sort which has been seen.

It is but a short step from the condition in figs. 26 and 27 to that seen in fig. 28, in which a bridge of tapetal cells, clearly distinguishable as such, extends completely across the loculus; it will be seen that, though in part it is a single row, some of the cells are divided in the plane of the septum, and this leads on to the state shown in fig. 29, where the septum is several layers of cells in thickness, while from either side an extension of tissue, of the nature not of tapetum only, but of permanent tissue of the septum, occupies the central region. Slight extensions of this permanent tissue may be seen also in figs. 26, 28, and 30A, thus illustrating how the permanent tissue extends inwards in rough proportion to the bulk of the septum. It is only a slight step further to the complete and normal septum permanently dividing the two loculi in the mature state; such septa are shown in fig. 30 between the sporangia *a*, *b*, *c*, and may vary in thickness, and in other details of structure, though they commonly consist of two to three layers of cells.

From the above description it will be plain that the sporangia of *Danæa* are by no means constant bodies; they are arranged in two rows, which together constitute the sorus, and this is perhaps their most constant feature. In point of segmentation of the cells which give rise to them, there is very great diversity of detail, though it appears that, as in other Pteridophyta, the essential part of the sporangia is referable in origin to superficial cells. But beyond this, in form and size of the sporangium, in the number of sporogenous cells, in the details of septation, and even in the details of dehiscence, there is an absence of constancy. Though many of the characters provide material for speculation, which will be taken up later, one conclusion may at least be drawn from the facts (it is, indeed, a mere summary of them), viz., that the sorus and sporangium of *Danæa* are distinctly non-specialised, perhaps more obviously non-specialised than those of any other living Pteridophyte.

Summary of Data from Study of Danæa.

(1.) The sori consist of numerous sporangia, arranged in two parallel rows, united into an oblong cake-like mass, partially overarched by indusia, which spring up between the sori, from the surface of the leaf.

(2.) The sori are not always strictly circumscribed, but are liable to abstriction, resulting in shorter, sometimes circular, sori.

(3.) The sporogenous tissue, together with the part of the wall immediately above it, arises by segmentation of superficial cells. Usually one such cell (the superficial parent-cell) supplies the whole sporogenous tissue of each sporangium.

(4.) There is a great variety of detail in the segmentation, and in the size of the resulting groups of sporogenous tissue; hardly any two are exactly alike. Sometimes more than a single parent-cell appears to be involved.

(5.) The tapetum originates from the cells immediately outside the sporogenous group; the tetrad division of the spore-mother-cells and maturing of the spores call for no special remark.

(6.) The wall of the sporangium, which consists of several layers of cells when young, may, by their collapse, be reduced in parts to a single layer when ripe. The dehiscence of the sporangium is by a simple rupture, in a radial plane, the resulting slit widening, as the adjoining cells shrink, to an almost circular pore. There is no annulus.

(7.) Where the sporangia are large, imperfect septations are frequently found, and many intermediate conditions have been found between the simple sporangium, and two separate and equal sporangia lying side by side.

(8.) In large sporangia the partial septa may owe their origin partly to encroachment of the tapetum upon the sporogenous tissue, but partly to sterile development of cells belonging to the sporogenous mass.

(9.) The number of spore-mother-cells in an average normal sporangium is estimated at about 432, and the potential number of spores would therefore be about 1728, or, in round numbers, about 1750.

KAULFUSSIA.

The structure of the sorus in this Eastern genus, which, as it were, replaces geographically the Western genus *Danæa*, has been repeatedly depicted and described,* but I am not aware of any account hitherto published of the development. The sori, which are circular in outline and without any indusium, are scattered irregularly over the lower surface of the ternate, or quinato-digitate leaf, being inserted upon the smaller nerves. The form of the sorus is like a shallow cup,* with crenate outer surface, the very slight grooves of the crenation being continued inwards over the margin; on the oblique inner face of each of the sporangia, which naturally correspond to the convexities of the crenation, there is in the mature state a narrow slit-like dimple, which indicates the point of dehiscence; but I do not find the pore to gape widely, as it is represented to do by F. BAUER. The number of the loculi is variable, as is also their size and outline. Further, the sori are not always of the circular form, but sometimes slightly elongated; others again show a median constriction, and it is easy to find examples, which, when placed side by side in series, would appear to illustrate all stages from the usual circular type, to two such sori seated as a pair (fig. 31, *a–e*).

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* By KAULFUSS, in HOOK and GREV., 'Icon. Filicum,' Plate 229; by GRIFFITH, 'Description of *Kaulfussia*,' p. 109; by FRANCIS BAUER, HOOKER'S 'Genera Filicum,' Plate 54; 'Monographie des Marattiacées,' DE VRIESE and HARTING, vol. 5.

The similarity of general character of this sorus to that of *Danæa* is obvious enough; the chief difference lies in the circular form. But it has been above noted that such circular sori are occasionally found on leaves of *Danæa*, especially on those which show characters intermediate between sporophylls and foliage leaves; in these not only is the distance between the sori often considerable, so that they lie isolated, almost as in *Kaulfussia*, but also the appearance of the sorus itself comes very near to that in the latter genus.

Turning now to the development, I have been able, through the kindness of Dr. M. TREUB, who sent me a large supply of material from Buitenzorg, to follow through the latter stages, though the material did not suffice for showing the earliest.

The youngest condition which I have seen is that represented in fig. 32, in which the sorus appears as a flat upgrowth from the general surface of the leaf, with a slightly raised marginal rim. The segmentation indicates that the whole has arisen by the division, and more active growth of a patch of superficial cells; those at the periphery have grown more actively than those lying centrally. The cells which will give rise to the sporogenous tissue lie immediately within the marginal rim of the young sorus. I have not seen the earliest stages, where the archesporium is represented by a single cell, but the youngest specimens I have seen leave no doubt that this is their mode of origin; thus in fig. 33 the shaded cells of the sporogenous tissue, together with the superficial cells which cover them, are evidently referable in origin to a single parent cell. It would appear doubtful whether the whole of the sporogenous cells are first segmented off by the periclinal wall, *b*, *b*; from the disposition of the cell walls here, as well as by comparisons of other sections, I am disposed to think that the wall, *a*, *a*, was formed first, and that a subsequent addition to the sporogenous tissue was made by the later wall, *b*, *b*; but I have not been able to decide this question by actual observation. The further steps in the

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* I find the cup to be much more shallow than it is depicted by FRANCIS BAUER.

development, as seen in sections radially through the sorus, will be gathered from figs. 34, 35, 36; from these it will be seen how the sporogenous group undergoes further segmentation, while they demonstrate that it is wholly referable in origin to that group already recognised in fig. 33. There is, however, a slower growth of the part involved, so that it is partially overarched by the surrounding tissue: thus the narrow slit-like dimple, already noted in the mature condition, is produced, but, as tangential sections (fig. 40) show, the dimple is very narrow.

Transverse sections (fig. 37) through the sorus of age corresponding to fig. 33, bear out these results; the sporogenous groups are easily distinguished at this stage, as packets of 2 or 4 cells; it is to be noted that neither at this, nor at any later stage, is there any indication that the intervening tissue represents the fused walls of confluent sporangia; the developmental evidence, though it does not directly disprove, does not in any measure contribute to prove any hypothesis of coalescence of distinct sporangia, either in this, or in other genera of Marattiaceæ. Later stages (fig. 38) show that there is no exact type or form of segmentation of the several sporogenous groups, a conclusion which might have been anticipated from comparison of fig. 37, as well as of the mature sporangia, and of the facts relating to *Danæa.*

Tangential sections of the sorus are difficult to obtain so as to give easily intelligible results, owing to the curved form of the sporangium; but if a section be cut in the direction XX, fig. 34, the appearance presented will be as in fig. 39, in which it is easy to see how the several tissues will correspond. An interesting fact which is brought out by such a section is that the groups of cells of the sterile tissue, which forms the septum between two adjoining sporogenous groups, are of similar origin with these, and at first differ in no respect from them, except in the less dense protoplasm, usually smaller nuclei, and in the fact that they do not eventually form spores. Very shortly after the stage shown in fig. 39, the growth of the tissue above the sterile septa becomes more active than that above the sporangia, and the result is the formation of a narrow slit-like depression (fig. 40); but as is shown by figs. 35, 36, 41, this extends only for a short distance in a radial direction, while its position is upon the oblique inner rim of the sorus. It is at the base of this slit that the rupture takes place at maturity, the cells adjoining it, both below and laterally, dry up, and the result is that the pore gapes open in much the same way as that described for *Danæa.* Here again, no mechanical tissue with thickened walls has been seen, which assists in the rupture, or in widening the pore when formed, while the actual rupture takes place in the cells which formed the cap of tissue directly covering the sporogenous group. Though differing in minor details, the dehiscence is thus seen to be essentially similar to that in *Danæa.*

Up to the time of dehiscence the external wall of the sporangia remains of considerable bulk; there is no markedly indurated superficial layer, and the wall maintains its massive character, the inner layers remaining distended without drying up as in other genera. It may be noted in passing, that the vascular bundle upon which the sorus is seated throws up an irregular extension into the base of the sorus, in the form of tracheids (fig. 42), the physiological importance of which is obvious enough.

Turning now to the sporogenous tissue, it undergoes subdivision in the usual way, till the definitive number of spore-mother cells is attained; these then separate from one another, and round themselves off in the fluid which fills the enlarged cavity of the sporangium. Then follows the tetrad division, all the cells of the sporogenous mass taking part in it in normal sporangia. A tapetum is meanwhile formed from the cells adjoining the sporogenous group, and these may grow and assume irregular form, encroaching on the cavity, as in the case of *Danæa.* In fact all the main features are the same as in other Marattiaceæ.

As in other genera, an estimate has been made of the average number of spores which may be produced from a normal sporangium of *Kaulfussia.* An average number of spore-mother-cells exposed in a single vertical section of a sporangium, radially through the sorus, is found to be 245; transverse or tangential sections show that the whole sporogenous mass is about eight layers in thickness; the total number of spore-mother-cells would therefore be about 1960, and the potential number of spores per sporangium about 1960 × 4 = 7840.

As regards the septa dividing the loculi, variations in thickness, and even partial septations have been seen. The usual thickness of the septum is of three layers of firm permanent tissue, with a layer of tapetum on either side—from this as normal (though its thickness may be exceeded), various simpler structures have been seen, down to a partial septum; in fact, though I have not thought it necessary to represent the facts by detailed drawings after this has been done so exhaustively for *Danæa*, the main features are similar to those in that genus.

Summary of Results from Study of Kaulfussia.

(1.) The sori are not strictly circumscribed, but are liable to abstriction, and even apart from such cases, the normal sori are often arranged in pairs on the lower surface of the sporophyll.

(2.) The sorus consists of a number of sporangia arranged almost in a circle, with no indusium.

(3.) The sporogenous tissue, together with the part of the wall immediately above it, arises by segmentation of a single superficial cell for each sporangium.

(4.) The tapetum originates from the cells immediately outside the sporogenous group.

(5.) An average number of spore-mother-cells in a single sporangium is about 1960, and the potential output of spores is therefore about 7840, or in round numbers over 7500.

(6.) The outer wall of the sporangia retains its bulky character up to the period of dehiscence, and there is no specially indurated superficial layer. The dehiscence is by a narrow slit, which opens by shrinking of the adjoining cells ; there is no annulus.

(7.) Imperfect septations are occasionally found, where sporangia are large.

(8.) The cells which give rise to the sporogenous group, and those which form septa are similar in origin, and at first are indistinguishable from one another.

Though the more general theoretical discussion will be reserved for a later page, it may here be remarked that the similarity of construction of the sorus of *Kaulfussia* to the larger one of *Danæa*, leaves no doubt of their near relationship. The main difference between the two is in size and outline, the absence of indusium, and in their being widely scattered over a large leaf area in *Kaulfussia*, while in *Danæa* they are closely arranged on a smaller leaf surface. But in those leaves of *Danæa* which show an intermediate condition between the sterile and fertile, the sori are frequently circular, and resemble in a remarkable degree those of *Kaulfussia*. Moreover, the similarity extends to the indusium ; for while in *Danæa* this rises between closely placed sori to a height almost equal to that of the sori ; where the sori are further apart the indusium appears only as a slight bank of tissue surrounding it. Thus the indusium is variable even in the genus *Danæa*.

From the above it would thus appear that as regards their sori, *Danæa* and *Kaulfussia* are fundamentally similar types, and that the chief points in which they differ are variable even in the individual of *Danæa*. It is further interesting to note that such variability in *Danæa* is associated with extension of leaf-area, and that the area of leaf of *Kaulfussia* is considerable ; this will be a point of importance in our theoretical consideration to be introduced below.

MARATTIA.

The sorus in the genus *Marattia* has been investigated by various writers, and is described more or less fully in the text-books ; this is a natural consequence of the material being readily accessible in Botanic Gardens, as well as in its native habitats. The mature structure of the sorus is thus well known, chiefly through the writings of LUERSSEN ('Beitr. z. Entw. d. Farn-Sporangien,' I.), and STRASBURGER ('Ueber *Scolecopteris elegans*,' p. 93, &c.). The development was examined first by RUSSOW ('Vergl. Unters.,' 1871, p. 109, 110), who showed that it arose from superficial cells, and that a number of these are involved in the formation of each sporangium. LUERSSEN followed, in 1872, with a much more complete account, illustrated by numerous drawings, chiefly from *Marattia cicutæfolia ;* but as the sections of the young sorus, which were represented and described by him, were only vertical sections through the sorus, and as the consecutive steps of development were not stringently compared, so as to elicit the mode of progression from one to another, and to show the exact origin of the sporogenous tissue, it is plain that much yet remained to be done. GOEBEL ('Bot. Zeit.,' 1881, p. 685) briefly notes his own observations on *Marattia cicutæfolia* and *alata*, and states that, as regards the archesporium, there is a complete similarity to that of *Angiopteris*, and that the archesporium is referable in origin to a single cell. He further regards the separate origin of the archesporia as evidence of the whole synangium being a sorus, and not a septate sporangium; in his outlines of classification (Engl. Ed., p. 254) he remarks that the fact of each sporangium having its own archesporium "proves that in *Marattia*, as in *Angiopteris*, we have two rows of distinct sporangia, which have grown together by their lateral faces." We shall inquire subsequently whether the facts are always as stated, and secondly whether this conclusion is really justified.

Since *Marattia* is a middle type of the family, it was thought useful to trace the origin and development of the sorus with the greater care, for purposes of comparison on the one hand with *Danæa* and *Kaulfussia*, and on the other with *Angiopteris*. Moreover, this could be carried out with greater certainty, owing to a plentiful supply of growing material of *Marattia fraxinea* (SMITH), which allowed of the earliest stages being traced.

The locality of the sorus in this species can be very early recognised, in sections which traverse it transversely, by means of the hairs which rise from its margin (fig. 45). The cells which will give rise to the sorus, though not yet projecting beyond the general surface, are deeper than those of the surrounding tissue; they are not constant either in number or form, nor in details of segmentation, as will be seen from figs. 45, 46, 47, 48; and this want of constancy of detail is a feature which is maintained all through the development of the sorus, showing a marked contrast to the regularity of the segmentations involved in the formation of the Leptosporangiate sporangium. Very soon the central region of the sorus is left behind by the more active growth on either side (figs. 46, 47, cells marked *x*), the sorus thus beginning to assume its characteristic form. It might already be concluded, from fig. 46, that there is no strict regularity of segmentation of the cells on either side of the median line, as seen in transverse section of the sorus; but this fact is still more apparent in a tangential section of the pinnule (fig. 47), in which the young sorus is seen in ground plan. In the stage there represented it is impossible to recognise with certainty which cells will ultimately give rise to the essential part of the sporangia, and which will form the sterile septa; all appear alike as regards contents, and equally indefinite as regards their segmentation. Similar results are obtained from a section longitudinally through the region where the sporangia will arise (fig. 47, section along line *b*, *b*, shown as fig. 48); here again it is impossible to distinguish the future septa from sporogenous cells. In representing the development of the sporangium of *Angiopteris*, GOEBEL ('Bot. Zeit.,' 1881, Plate 6, figs. 4 and 5) enumerates certain anticlinal walls, thereby implying that there is in that genus a constancy in their number and appearance, while he further points out that there is a constant relation of these to the origin of the archesporial cell, which is described as the "hypodermal terminal cell of the central row of cells" ('Outlines,' p. 254). In *Marattia* I am not able to recognise such constancy; from figs. 45, 46, 47, and 49, but especially from fig. 47, it would be concluded that, while examples could easily be found which would correspond with some approach to exactitude to the plan laid down by GOEBEL for *Angiopteris*, such a plan is not rigidly maintained in *Marattia*, and that it is most conspicuously departed from at the ends of the sorus. Moreover, a comparison of the two opposite halves of the same sorus, as seen in section, shows that they are not strictly dominated by a common plan. A comparison of numerous serial sections, of various ages, leads to a further conclusion that the whole archesporium is not always referable to a single cell, though it seems to be so in most cases. Fig. 50 shows a rather older sporangium in section, and it would appear in that case of a rather undersized sporangium, that the whole sporogenous group may be referable to a single parent cell. In more bulky cases, however (fig. 51), it is difficult to trace such an origin, and it would appear more probable in large sporangia that the sporogenous group originated by the periclinal division of more than a single cell, as is indicated in figs. 46 and 49.

Transverse sections of the sorus have been compared in order to give solidity to the conception of its structure; they again demonstrate the variety of detail. The common type is seen in fig. 52, and it will be noted how this section coincides with what would be seen if the sporangium in fig. 51 were cut in a plane, *cc*. But the subdivision of the archesporium is subject to variation (fig. 53), the extreme cases of which will be considered later. To complete the study sections of the sorus of the same age as figs. 50–53, were cut so as to traverse it longitudinally (compare fig. 48); the result is such as might have been anticipated; it must be remembered in comparing this with the other sections that the anticlinal walls are curved, and that consequently the majority of the cell-rows in fig. 54 will be traversed obliquely; thus their genetic relations are apt to be obscured.

It is not difficult to follow the sporogenous group and its surrounding tissues from the conditions shown in figs. 50–54, to the older stage immediately preceding the tetrad division; this is a condition in which the grouping of the tissues is still sufficiently maintained to serve as evidence of the mode of origin, while on the other hand the cells which will actually form spores can be distinctly recognised by their contents, without any probability of error. Sporangia of such age are represented in figs. 55, 56, 57, respectively, in radial, tangential, and transverse sections. The examples chosen are those which show an average structure, though many deviations from the type occur, which will be discussed later. The tapetum originates outside the sporogenous group, from the cells immediately surrounding it; the latter is at this stage a laterally compressed, disk-shaped mass of approximately cubical cells. The wall of the sporangium in *M. fraxinea* is more massive than is represented in LUERSSEN's figures of *M. cicutæfolia*, while also the number of the sporogenous cells appears to be larger (*loc. cit.*, Plate 21, fig. 7). It will be noted that the wall is narrowest on the flat face where the two sides of the sorus are in contact; it is here that the dehiscence ultimately takes place, after the two halves of the sorus have gaped apart. The wall here consists of two layers of permanent tissue, within which lies the tapetum. The further details of structure of the sporangium when mature, and of its dehiscence, have been so well treated by **LUERSSEN** and **STRASBURGER** that there will be no need of a further description here.

Bearing in mind the variations in detail to which the sporangia are liable, we may form an estimate of the output of spores from an average sporangium, as calculated from the number of spore-mother-cells. Proceeding on average examples such as those shown in figs. 55, 56, 57, which were specially selected as examples of a medium type just before separation of the spore-mother-cells, we find in the vertical section (fig. 55) 166 spore-mother-cells. Figs. 56 and 57 show that the laterally compressed sporogenous mass is on the average rather over four layers in thickness, and the total number of spore-mother-cells in an average sporangium may therefore be computed at about $166 \times 4 = 664$. The resulting potential output of spores would then be about $664 \times 4 = 2656$, say, in round numbers, 2500.

Having so far described the development of sporangia of the type which may be considered the average for *Marattia fraxinea*, it remains to consider the deviations from that type; these, as in other genera, have a special interest in connection with the main lines of this investigation. It has already been shown that it is often difficult in average cases to refer the sporogenous group in origin to a single archesporial cell; it will be presently seen that in certain extreme cases more than a single archesporial cell must have been involved.

An examination of any sorus of *Marattia* in which the sporangia are approaching the tetrad division, and in which, accordingly, it is possible on the one hand to note with certainty the cells which will form spores, and on the other to still recognise their genetic relations, shows that the size and structure of the sporogenous groups is very variable. The details are most readily traced in transverse sections of the sorus, and from these the drawings to be discussed have been made. In fig. 57 an average example has been shown; but as a specimen of the differences of detail, which may frequently be seen, the three sporangia shown in fig. 58 will serve; no two of these are alike in size or shape, or in the segmentation; it is, however, possible to refer the sporogenous group in each case to a single parent cell. As extreme examples of small size, the figs. 59, 60 may be quoted, which were drawn from sori of the same age as fig. 58, and to the same scale. But not unfrequently sporangia are found in which the grouping of the sporogenous cells is such that they appear not referable in origin to a single cell; such cases are shown in figs. 61, 62. In the former there are two groups of cells, which are not exactly opposite one another, while the line which separates them is continued on as an obvious line of early cleavage to the anterior and posterior faces. In fig. 62 it would appear probable from their grouping that the sporogenous cells originated from three parent cells. Such cases as these are to be noted in connection with partial septations, which are found to occur in *Marattia* in somewhat the same forms as in *Danæa*. Two examples are shown in figs. 63 and 64, which represent a rather more advanced stage of development than the preceding drawings. In fig. 63 we see a sporangium of very large area; the sporogenous tissue is encroached upon by ingrowths of the nature of tapetum; in one case these extend completely across the loculus, so as to form a septum; and it was seen, from comparison of the series of sections through this sporangium, that the septum was a complete one, but being only composed of tapetal cells it would not have been apparent in the sporangium in the mature state. In fig. 64 a more complete septation is represented, the sporogenous group being partitioned as before by a plate of tapetum, but, in addition, ingrowths of permanent tissue project on either side into the sporangial cavity. A comparison of such examples as these with those described above for *Danæa* (figs. 26–30) shows that the cases are essentially similar; thus in *Marattia* also the identity of the sporangium is not always strictly defined, a point which will have special interest in connection with the theories which will be subsequently discussed as to the nature and mode of origin of the synangia.

An excellent account of the gaping of the two-lipped sorus, and of the dehiscence of the sporangia having been given by LUERSSEN (*loc. cit.*, p. 21, &c.), it will be unnecessary to enter into the details again. It need only be remarked that, apart from the gaping of the sorus as a whole, the dehiscence of the individual sporangium is of the same type as is seen in *Danæa* or *Kaulfussia*, involving contraction of cells by drying, while the efficiency of this is increased by the fact that the softer dehiscent tissue is set in a firm resistant peripheral frame, which makes it necessary that the process of drying shall widen the fissure. At maturity the wall of the sporangium, apart from the region of dehiscence, consists of a firm superficial layer, with the more or less contracted remains of the inner layers of the wall still visible.

Summary for Marattia.

(1.) The segmentation of the young sorus leading to the formation of sporangia is not constant in detail.

(2.) The sporogenous tissue together with the part of the wall immediately above it arises commonly by segmentation of one superficial cell.

(3.) But there is frequently a variety in detail of the segmentation and in the size of the sporogenous groups; in some cases the whole group is not referable in origin to a single archesporial cell.

(4.) The tapetum arises from cells adjoining, and outside the sporogenous groups.

(5.) There is a mechanical tissue which has the function of making the two sides of the sorus gape apart at maturity; the dehiscence of the individual sporangia is by slits in radial planes, the gaping of which is brought about by contraction of thinner walled cells surrounded by a more firm and resistant frame. The wall at maturity retains evidence of its massive structure.

(6.) Imperfect septations are found in some sporangia, similar in their main features to those already described in detail for *Danæa.*

(7.) The potential number of spores initiated in an average sporangium, reckoned from the number of spore-mother-cells, is (4 × 664) = 2656, or in round numbers 2500.

Angiopteris.

The sori of this genus have been more thoroughly investigated than those of any of the preceding genera of Marattiaceæ. Their mature structure, as seen from above, has been illustrated in many systematic works with varying success: the best drawings are those by STRASBURGER in his memoir on *Scolecopteris* ('Jenaische Zeitschrift,' 1874, Taf. 3). The general nature of the sorus, with its separate sporangia, is so well known as to require no description of its external characters here.

The development was traced by TCHISTIAKOFF ('Ann. Sci. Nat.', 1874, Ser. 5, vol. 19, p. 219, &c.): he found that each sporangium originates from several cells, while he refers the sporogenous tissue to a single parent cell; but the drawings, which are only of radial sections, do not exactly demonstrate the relations of this cell to the rest. LUERSSEN ('Handbuch der Syst. Bot.,' 1879, p. 578), also examined young sori of *Angiopteris,* and gave a drawing of a sorus cut longitudinally: but he specially notes that the cell-group which gives rise to the mother-cells of the spores is never referable in origin to a single central cell. GOEBEL ('Bot. Zeit.,' 1881, p. 681, &c.), on the other hand, found the case of *Angiopteris* to be similar to that of *Botrychium,* and recognised as the archesporium the hypodermal cell of the axile row of cells of the young sporangium: this he asserts gives rise to the whole sporogenous tissue. He notes how the sporangium grows more strongly on its outer side, thus acquiring an unsymmetrical form; in his figures (Taf. 6, figs. 4 and 5) he numbers certain anticlinal walls in sporangia of successive ages, and indicates the relation of the archesporium to these; thereby giving the impression that there is a certain constancy in the occurrence of these walls. The tapetum originates from the cells outside of and surrounding the archesporium, but he states that it is not of long duration, being soon disorganised. This statement is however corrected by CAMPBELL ('Mosses and Ferns,' p. 272), who points out that the cells of the tapetum, which often have numerous nuclei, do not break down early, but remain at least up to the tetrad division of the spore-mother-cells. He gives also a figure (fig. 143) of a sporangium approaching maturity in median section, and this together with the drawings of STRASBURGER, *loc. cit.*, Taf. 3, figs. 14–18, are hitherto the best illustrations of the structure of the whole sporangium: STRASBURGER'S figures and description show especially the mode of dehiscence by a slit on the inner face, while a group of indurated cells, occupying the apex of the sporangium, act as a sort of annulus, performing an essential part in the mechanism of the dehiscence. The structure of these indurated cells, and their relation to the rest of the wall has also been described and figured by ZEILLER ('Bassin Houiller et Permien d'Autun et d'Epinac,' Fasc. 2, p. 19, figs. 12 and 13). It will be seen that his statements and drawings will harmonize with the description given below.

Using in part specimens from the Royal Gardens, Kew, partly material from the Glasgow Botanic Garden, I have followed the development of the sorus in *Angiopteris* from the earliest stages, and find that there is a general similarity at first to that of *Marattia*, as above described; the same want of constancy in details of segmentation is apparent. At an early stage the individual sporangia begin to project as separate upgrowths, but I find it impossible, from a study of superficial sections, to detect any regular system of segmentation which is maintained in all sporangia; a comparison of the four sporangia, shown in fig. 65 in surface view from above (in which the sporangia are indicated by shading), discloses no regular sequence of segmentations, and the cell-groups which will develop into the sporangia appear consequently ill-defined. I do not propose to attempt an exhaustive description of the variations of detail which may be found in organs which are thus variable from their earliest stages, but to give an account of the most central and frequent type of development. Of the sporangia a, b, c, d, shown in fig. 65, that marked (b) is believed to be the most regular and usual type; and the cells shaded in it are evidently sister cells, derived from a single parent cell which, as we shall see, gives rise to the central and essential part of the sporangium; we may call this, as in the other genera, the superficial parent cell. If a section were taken along a line $x - x$ through such a sporangium, after it had grown more convex, it would appear as fig. 66, in which the cells shaded are believed to correspond to those shaded in fig. 65. It becomes apparent from such sections as these that a single cell, the central cell, had divided periclinally to form an inner cell and a superficial one; the former is the archesporium, and has in fig. 66 already divided into two; the superficial cell has also divided repeatedly. Tangential sections (*i.e.*, vertical sections at right angles to $x - x$, fig. 65) do not greatly aid our idea of the developing sporangium, and are unsatisfactory owing to the inward curve which it assumes as a consequence of the stronger growth on the peripheral side of the sorus: such a section is shown in fig. 67. Though we may thus select sections so as to represent a reasonably regular and typical structure of the young sporangium, it is clear, from fig. 65, that what has been described is only a central type, and as a matter of fact hardly any two sporangia show exactly the same details of segmentation. A comparison of our central type, as illustrated in fig. 66, shows substantial correspondence with the drawing of GOEBEL ('Bot. Zeit.,' 1881, Plate 6, fig. 4), while even the walls which he numbered 1–5 may be compared with the principal walls in our fig. 66; but since we find that these are not constant, this correspondence in detail cannot be considered of material importance. An older sporangium of typical structure is shown in fig. 68, and it is an easy matter to see how such a younger sporangium as fig. 66 might develop into it; the correspondence again with GOEBEL'S fig. 5 is sufficiently close to confirm the accuracy of his observations for certain average cases. Transverse sections of sporangia of this age show the great variability of segmentation, even in sporangia of approximately equal size. A common type is, however, that of fig. 69, which corresponds in essentials with a section along the line $x - x$ through fig. 68 ; the sporogenous group is of the same construction, but the tissue on the peripheral side of the sporangium is rather more bulky ; in this matter, however, variations are common. Finally, tangential sections at this stage confirm the results hitherto obtained : one of the most regular, though from a bulky sporangium, is shown in fig. 70 ; a comparison with fig. 68, if we imagine it cut through along the line $y - y$, will sufficiently explain itself. From these three sections of typical sporangia, of an age to show the sporogenous group already recognisable, a good idea of it as a solid body will be gathered. The sporogenous group is clearly referable in origin to a single cell, while the portion of the wall included in the bracket in figs. 66, 68, was derived from its superficial sister cell. The essential part of the sporangia is thus referable in ultimate origin to a single superficial parent cell, as has been found to be the case typically for other Marattiaceæ, and for *Botrychium*, *Helminthostachys*, and *Equisetum*. The wall of the sporangium, as yet undifferentiated, consists of a tissue of variable thickness, being thinnest on the side next the centre of the sorus, and thickest on the peripheral side. I do not find constancy either in position or number of the segmentations in the wall of the sporangium, on comparison of numerous sporangia one with another. Continuing the development of the most regular type of sporangium, growth and cell-division often continue with sufficient regularity to allow the genetic grouping of the tissues to be clearly followed (fig. 71). Meanwhile, a group of cells at the apex enlarge to form the crest-like annulus. The relation of this to the main lines limiting the product of the superficial parent cell is variable ; a common case is that in fig. 71, where the middle line (x) coincides with the limit of the annulus ; but this is by no means constant : from this point (x) downwards, on the central side of the sporangium, the dehiscence will take place. The sporogenous group is now clearly defined by the character of its protoplasmic body, and it forms a definite block of cells, referable to a single parent. Next follows the change of the cells immediately surrounding the sporogenous group, to the character of tapetum (fig. 72), and it may be stated that though questionable cases are frequently seen, the type appears to be that the whole tapetum is extra-archesporial in its origin. The figs. 72, 73, 74, represent respectively in radial, transverse, and tangential sections, sporangia which have arrived at the stage of complete division of the sporogenous mass, and in which the spore-mother-cells are about to separate and round themselves off, prior to the tetrad division.

From such sporangia it is possible to compute the average number of spore-mother-cells, and for this purpose a number of countings have been made. In radial sections the average of the countings gave 59, say in round numbers 60, spore-mother-cells traversed. Tangential sections show, on the average, about 6 such layers of cells to be present, and the average number of spore-mother-cells in each sporangium would thus be 6 × 60 = 360, while the average potential output of spores per sporangium would be 360 × 4 = 1440 spores. I have no details to add to what is already known of the tetrad divisions of the spore-mother-cells, and their progress to the maturing of the spores. It may be noted that, in the cases observed, all the spore-mother-cells undergo the tetrad division, and none have been seen to be disorganised, though this, doubtless, may occur in some cases.

Reverting to the tissues outside the sporogenous group, the tapetum is not a strictly defined layer, and is often irregularly doubled by periclinal divisions; but this is by no means always the case, as will be seen from a comparison of figs. 72–74. It remains recognisable as distinct, enlarged, glandular cells, often with several nuclei, up to the period of the tetrad division. This has been noted by CAMPBELL ('Mosses and Ferns,' p. 273); but, as the spores become mature, the tapetal cells lose their definite outline, till all that remains of them is a peripheral granular residuum lining the sporangial cavity (fig. 75). The wall of the sporangium outside the tapetum consists of two or more layers. commonly three, of which the outermost is the firmest and most differentiated; the inner layers are less regular, and are composed of more or less tabular cells. I have never seen the tapetum in direct juxtaposition with the superficial layer, as it has been figured and described by CAMPBELL (*loc. cit.*, p. 273, and fig. 143, C.). Of the external wall three essential parts may be recognised, and they will be best seen in fig. 76, which represents the apex of the sporangium, cut off in such a plane as *x*, *x* in fig. 72. The first part (*a*, fig. 72) is found on the dorsal (peripheral) side of the sporangium, and consists of large turgid cells, with moderately thin walls, and granular contents, which stain deeply with Bismarck brown. A second region (*b*) consists of deep prismatic cells with thick lignified walls, which may be recognised as the annulus; it extends as a narrow bridge across the apex of the sporangium (fig. 72), and widens out on either side, as the apex is left, into a broader band of cells with lignified walls (fig. 77). The third region (*c*) consists of thinner walled cells, of elongated form, which constitute a narrow band (fig. 75) running down the anterior (ventral) side of the sporangium. This is the tissue adjoining the fissure of dehiscence, and the structure which thus determines it is comparable to that seen in *Gleichenia* (CAMPBELL, fig. 185, B), or *Osmunda* (CAMPBELL, fig. 184). The above description corresponds in all essentials to the account given by STRASBURGER ('Ueber *Scolecopteris*,' p. 91).

The structure of the sporangial wall being as thus described, we may now consider how it works in connection with dehiscence. The annulus, together with the two broader lateral extensions of it, constitute a firm resistant arch, of which the apex is the narrowest part, being only about three cells wide (figs. 72, 76). If the thinner-walled posterior region (*a*) were to contract, as we may presume it does by drying as the sporangium matures, the two sides would be pulled backwards, while the thin bridge of the annulus at the apex would act as a sort of semi-rigid hinge; the line of dehiscence on the ventral face, having been structurally defined, would thus, on fission, be caused to gape widely. It is not probable, however, that this hinge-like action is very considerable, and the gaping of the slit may be mainly due, as in other Marattiaceæ, to mere drying up of the cells in the neighbourhood of the rupture.

At maturity the more or less indurated superficial layer of cells of the sporangial wall is the most conspicuous part, but the thinner-walled cells lying within, though they may shrink, do not entirely disappear.

Angiopteris.—*Irregularities.*

It has been repeatedly noted that there is no definite strictness of segmentation in the sporangium of *Angiopteris,* though it is possible to fix upon a central type which is reasonably definite. It remains now to mention some of the more marked deviations from that type, but the attempt will not be made to follow out the less obvious variations.

As regards size of the sporangium, there is certainly a greater uniformity than in *Danæa* or *Marattia*, and very many sori may be examined without finding marked differences; but such differences do occur, and fig. 78*a*, *b*, *c*, will serve as a sufficient illustration; the large terminal sporangium in (*c*) is specially worthy of note as being a synangium, which is distinctly uncommon, though the terminal sporangia are frequently larger than the rest.

The series, figs. 79, 80, 81, illustrate what is perhaps the most interesting deviation from the normal. Fig. 79 shows a normal sporangium from the same pinnule as the others, with the usual structure, and a well-defined sporogenous group already segmented. Fig. 80 shows an unusually large sporangium, in which the sporogenous group is not regular, nor clearly defined; in the region where this should be, a number of cells with characteristic large nuclei are seen, not constituting a regular group, but spread over a considerable area. Fig. 81 shows a still more peculiar case, the structure of which at once suggests the synangial condition; the size of the whole sporangium is approximately double that of the normal (fig. 78*c*.); the sporogenous tissue, again ill-defined and rather irregular, appears to constitute two groups, which thus support the view of this as a synangium. A comparison of such cases, which are however by no means common, with those above described for *Danæa* and *Marattia*, shows such close similarity, that the conclusion is justified that the phenomenon is really one of partial septation of an enlarged sporangium such as occurs much more commonly in those genera than in *Angiopteris.*

Summary.

(1.) The segmentation of the young sorus, leading to the formation of sporangia, is not constant in detail.

(2.) The sporogenous tissue, together with the part of the wall immediately above it, arises commonly by segmentation of one superficial parent cell; but irregularities may be found.

(3.) The sporogenous group is commonly referable in origin to a single archesporial cell, but the segmentation is variable, and exceptions do occur.

(4.) The tapetum is an ill-defined band, one or two layers in thickness; it originates outside the archesporium, and remains till after the tetrad division, but is absorbed before maturity of the spores.

(5.) The annulus is a crest of cells at the apex of the sporangium, and is continuous with two lateral bands of indurated cells to form an arch: the rupture is determined, on the ventral face, by special thin-walled cells.

(6.) Abnormally large sporangia, and even synangia, though rare, are occasionally found.

(7.) The potential number of spores initiated in an average sporangium, reckoned from the number of spore-mother-cells, is (4 × 360) = 1440, or in round numbers about 1450.

General Comparison of Results for Sori of Living Marattiaceæ.

In the above pages details have been given of the development and mature structure of the sorus in each of the four living genera of the Marattiaceæ. Ferns allied to these constituted a prominent feature in the early fossil Flora. It will be our duty presently to compare these with our living genera as regards their fructifications. But as the fossils are only known to us imperfectly, and in the mature state, while we have the advantage of being able to study the living forms developmentally, it would seem most satisfactory first to consider these more completely known modern survivors.

On comparing the mature structure of the sorus as a whole, and that of the constituent sporangia, and taking in also the facts of development, it will be apparent that the four living genera follow one type, and that they form, notwithstanding certain external differences, a very natural family. The genus which appears externally to be most aberrant is *Kaulfussia*; but a comparison of the sorus, and especially its development, shows that in all essential features the sporangium and sorus are of the same type as in the other genera; the apparent peculiarity depends on the outline of the leaf, which is not a dependable character.

The sorus in all the living genera shows the sporangia disposed in a peripheral series, each sporangium being developed with reference to a radial plane, which at maturity coincides with its more or less elongated fissure of dehiscence. As this type of sorus is not found exclusively in the Marattiaceæ, and seems an important one from a theoretical point of view, I propose to designate it by a definite term, such as "*the radiate uniseriate sorus.*" The outline of the sorus may be almost circular, as in *Kaulfussia*, or more elongated, as in *Marattia* or *Angiopteris*, or greatly elongated, as in *Danæa;* but in all these the uniseriate arrangement of the sporangia is maintained, and the line of dehiscence, whether it be an elongated slit as in *Angiopteris*, or a short slit which widens on drying into an almost circular pore as in *Danæa*, is included in a plane running radially towards the central point, or towards the median line in those cases where the sorus is elongated.

As to the relation of the sporangia to one another, the living genera show important differences. In *Danæa* and *Marattia* the individuality of the sporangia is barely indicated by a slight convexity of the outer surface of each sporangium when mature, while the young sorus appears as a smooth upgrowth. In *Kaulfussia* the individual sporangia are not much more clearly marked externally, but in *Angiopteris* they project at an early stage as separate convexities, and in the mature state, though slightly united at the base, they rise upwards as almost separate rounded bodies. These facts may be taken as representative stages in a morphological series, and the similarity of development in the four genera would support that idea. Moreover, as we shall see, the fossils provide other examples which amplify the series. As in other morphological series, however, the facts may be taken as illustrating either of two views; in this case either a progression from a coherent to a separate condition of the sporangia, or a progressive fusion of them. This question will be considered again later, when the fossils have also been brought into the comparison.

The existence of a specialised mechanism for dehiscence of the individual sporangium appears to run parallel with the separate projection of the individual sporangia. In *Danæa* and *Kaulfussia*, in which the sporangia are closely united laterally, no indurated tissues have been found which can be held to act as an annulus for the mechanical widening of the slit of dehiscence. In these genera the slit, once formed, gapes merely by reason of the collapse of the neighbouring cells. Nor would it be possible, by any simple use of mechanical tissue, to improve upon this method, where the loculi are merely separated from one another by thin septa. In the sorus of *Marattia*, as has been fully described by LUERSSEN (*loc. cit.*, pp. 21–26), there are mechanical tissues, but their chief function appears to be that of bringing about the wide gaping of the two lips of the sorus, which precedes the dehiscence of the individual loculi; this change of form is a necessary prelude, since in earlier stages the two faces, upon which the dehiscence will take place, are in close contact, facing one another. The well-known change of form and wide gaping of the two lips of the sorus is brought about by certain masses of mechanical tissue lying about the base of the sorus. But for the actual dehiscence of the loculi themselves, the mechanism is of the simplest, and compares closely with that in *Danæa*. In *Marattia*, while the greater part of the sporangial walls, and even the septa are more or less indurated, the region of the wall where dehiscence takes place is composed of thin-walled cells; these rupture by a somewhat irregular slit, and the fissure widens by the drying and contraction of the adjoining cells. The firmer tissues of the remainder of the wall constitute a resistant framework, so that any such contraction widens the slit once formed. The simple arrangement is, as regards the individual sporangium, quite like that in *Danæa,* though complicated by the change of form of the whole sorus as it ripens; and together with the simple structure goes the absence of individual projection of the sporangia.

But in *Angiopteris,* where the sporangia are freely projecting bodies which do not exercise a controlling influence upon one another at the time of dehiscence, and thus leave free scope for change of their form, a more elaborate mechanical system is present, and I have endeavoured above to explain how it works.

When we place the above facts in connection with those familiarly known in the Gleicheniaceæ, Osmundaceæ, and the main body of Leptosporangiate Ferns, we see that *the presence of an annulus, and its elaborateness, are to be correlated with the freedom of the sporangia from mutual relations with others;* it is a mechanism—and in the Leptosporangiates a most wonderfully specialised mechanism—which is produced only in those forms where it has an opportunity of working; its office is to induce a change of form of the sporangium on rupture, and this can only be carried out when the single sporangium is free from its neighbours. As regards its presence or absence, *Danæa* and *Kaulfussia* may be cited as the least specialised of Ferns, excepting, perhaps, the Hydropterideæ.

It has been shown, in the detailed description given above, that in all the four genera the typical mode of origin of the sporogenous group, together with the group of cells lying immediately above it, is from a single superficial cell, with a square base, which I have designated *the superficial parent cell.* It is true that examples occur where it is impossible to refer the whole sporogenous group to so simple a source, but, though these are of peculiar interest from a theoretical point of view, the simpler origin is undoubtedly the type for the Marattiaceæ. The more superficial products of this cell develop into that part of the wall which covers the loculus, including the greater part, though perhaps not always the whole of the tissue of dehiscence. According to the unequal intercalary growth of the sporangium, this region of dehiscence may face directly upwards, as in *Danæa;* or it may, owing to stronger growth of the peripheral side of the sporangium, face obliquely inwards, as in *Kaulfussia,* or *Angiopteris;* or, finally, the surface of dehiscence may, owing to strong growth on the peripheral side, be turned into a vertical plane, as in *Marattia.* Here the two sides of the sorus are closely appressed till nearly mature, when they gape apart, owing to the mechanism above alluded to, and the dehiscence takes place on the faces thus exposed. All these are to be regarded as secondary differences, and, in all cases, the surface of dehiscence is similar in origin, the tissues involved originating mainly, if not always exclusively, from the outer products of the superficial parent cell.

The inner-lying products of this cell form the sporogenous group, of which all the spore-mother-cells appear normally to undergo the tetrad division. A point of special interest is the number of spore-mother-cells produced, and, in estimating this, it is hardly necessary to reiterate how variable the individual sporangia are, and that the estimates are based upon such as appeared to be normal average specimens. The numbers, as above stated, are :—

	Spore-Mother Cells.	Output of spores in round numbers.
Angiopteris	360	1450
Danæa	432	1750
Marattia	664	2500
Kaulfussia.	1960	7850

Now, these numbers are in great excess of those hitherto stated for any ferns. The estimates for Leptosporangiate ferns involve commonly such numbers as 48–64 spores per sporangium, while certain genera (*Aneimia*, *Osmunda*, &c.), have been described as producing a larger output, rising in the case of the latter genus to about 500; even this number is considerably exceeded by species of *Gleichenia*. But still there is a wide margin in favour of the Marattiaceæ. Beyond drawing attention to this fact I do not propose to go at present, but reserve the whole question of output of spores for discussion in a later paper, which will embody facts derived from the Leptosporangiate ferns. It may, however, be remarked that the large output of spores gives a physiological justification for the deeply-seated sporangia, and their broad base—in fact, the Eusporangiate condition is that best adapted for maturing large numbers of spores from the individual loculus.

The tissues which surrounded the superficial parent cell provide the rest of the wall of the sporangium and the tapetum; this latter tissue arises outside of, and genetically distinct from the sporogenous group. There are, however, occasional abnormalities of origin of the tapetum, and of the sporogenous cells, which will be discussed later. As a general rule, all the Marattiaceæ show this difference from Leptosporangiate ferns, that in the latter the tapetum is cut off from the sporogenous parent cell itself, but, in the Marattiaceæ, it originates from the tissues outside the sporogenous cell, or group of cells.

If we compare the Marattiaceous sporangium with that of the Leptosporangiate Ferns, the chief differences are seen to be :—

(1.) The broader base of insertion, and origin from a bulky group of cells.

(2.) The closer relation of the sporangia to one another.

(3.) The thicker sporangial wall, consisting at maturity usually of more than a single layer of cells.

(4.) The less specialisation of the mechanism of dehiscence.

(5.) The larger number of spore-mother-cells produced.
(6.) The cubical or prismatic, in place of the conical archesporial cell.
(7.) The origin of the tapetum from cells outside the sporogenous group.

It will be a matter of interest later to see how far these characters are absolute and distinctive. There are, in fact, certain ferns (Gleicheniaceæ, Osmundaceæ, and Schizæaceæ) which provide important material for comparison, and they show that the Marattiaceous type is not so isolated among ferns as it is often assumed to be.

NOTES ON FOSSIL MARATTIACEÆ AND ALLIED FORMS.

Having now seen that, though differing in certain features of the mature sorus, the four genera of living Marattiaceæ conform to one type as regards their development, and so would appear to constitute a very natural family, we may turn to the consideration of allied fossils. But I shall not attempt to give an exhaustive account of fossil ferns of presumable Marattiaceous affinity. This would bring with it little advantage, since so many are merely known by impressions, and the interpretation of these may often be doubtful. I shall only cite such examples as are reasonably well preserved, and are accordingly reliable for purposes of comparison.

Among the four living genera, notwithstanding the differences in form of the sporangium, in the number of sporangia in the sorus, and in the degree of their lateral connection with one another, there are essential points of similarity, such as the position of the sorus on a nerve, the uniseriate radial type of its construction, the relatively thick sporangial wall, and introrse dehiscence by a slit in a radial plane, and the deficient or absent annulus. Among the fossils there are various genera which conform to the modern Marattiaceæ in all these particulars. We shall first take those which are best known, and conform most completely to the modern types: of these *Scolecopteris* naturally takes the first place.

This genus, founded by ZENKER, has been extended by STUR* so as to include certain ferns previously described as species of *Pecopteris*. This author gives also very full references to the literature, and especially to the writings of STRASBURGER† and RENAULT.‡ As extended by STUR, the genus includes plants with sessile or shortly pedunculate sori, of three to six sporangia; they are united below, but separate above, and extend into a more or less elongated beak. The Marattiaceous characters are unmistakable, and it has been pointed out by STRASBURGER (*loc. cit.*, p. 87) that *Sc. elegans* (ZENK.) shows features connecting it with *Marattia* as regards the form of the sporangia, and with *Kaulfussia* in their circular disposition in the sorus, while the outline of their upper free portion would point to *Angiopteris:* in dehiscence it compares with all three, but especially with *Marattia.* *In fact,* Scolecopteris elegans *is a type which unites in itself characters of various living genera.* Other species of STUR's genus show differences of detail, such as greater or less length of the receptacle; this is what is seen among living species of *Marattia:* or the varying length of the terminal beak, of which *Sc. polymorpha* (BGT.) is an extreme case: this, though peculiar in being an extension of individual sporangia, may be compared with the differences of upward extension of the tip of the sorus in various types within the genus *Marattia:* so that this variability is not without its parallel among modern ferns of a single genus (compare LUERSSEN, *loc. cit.*, Plate 21). It may be noted that the number of sporangia in the sorus of *Scolecopteris,* which we thus on other grounds regard as a central type, is small and variable, but that 4 and 5 seem to be the most frequent numbers.

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* 'Sitz. d. Wiener Akad.,' Vol. 88 (1885), pp. 720–757.

† STRASBURGER, 'Jenaische Zeitschrift,' 1874, p. 81.

‡ RENAULT, 'Cours de Bot. Foss.,' III. p. 116, Plate 20. &c.

The fossil ascribed by STUR* to the genus *Scolecopteris,* under the name of *Scolecopteris cyathea* (SCHL., *sp.*), with its sporangia united below, but with free acuminations, leads on towards the genus *Asterotheca* (PRESL).† Here the circular sori consist of 3-8 sporangia, which are united almost up to the apex, they have the peripheral wall strongly convex, and show no annulus. The mode of dehiscence has not been directly observed, but it seems highly probable that it is by radial slits, which opened upon the small dimple-like depression at the apex. The whole sorus is strongly suggestive of that of a *Kaulfussia,* with a smaller number of loculi, and much narrowed apical depression, while the obscure slits of dehiscence of the modern genus, and the absence of any annulus would correspond to the condition of this fossil. PRESL has grouped this genus with *Kaulfussia,* but STUR (*loc. cit.*, p. 720) rejects this on the ground of the form of the leaf, which is closely similar to that of *Marattia Kaulfussii* (J. SM.); and he accordingly founded the special group Asterotheceæ. But to those who fully recognise how greatly the outline and character of the leaves of modern living ferns may vary within the single genus, this point would seem to be over estimated. I see in it no sufficient reason for separating the Asterotheceæ from *Kaulfussia.* In any case the correspondence between the sori seems to be a peculiarly close one. It may be noted that *Asterotheca* is a relatively early form,‡ a fact which has its importance.

Ptychocarpus (= *Diplazites,* GOPP.) *hexastichus* appears to have sori of a similar type to *Asterotheca,*§ but the sori are placed "in several rows on both sides of the median nerve in each pinna,"|| a condition which has its interest for comparison with *Kaulfussia.*

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* *Loc. cit.*, p. 752.

† STUR, *loc. cit.*, p. 704.

‡ *Ibid.*, p. 720.

§ *Ibid.*, p. 763.

|| SOLMS, *loc. cit.*, p. 144.

A very important fossil for comparison with *Kaulfussia* is that recently described, with new drawings, by RENAULT ('Gîtes Mineraux Fasc.,' 4, pp. 9–11), as *Pecopteris* (*Goniopteris*) *unita* (BRONGT). It is found throughout the whole thickness of the Upper Coal Measures (*loc. cit.*, p. 5). The synangium figured in transverse section consists of seven loculi, completely fused to a circular form, with an outer wall consisting of several layers of cells, while the septa are relatively thin. The central mass of tissue is occupied by a vascular axis of star-like appearance in transverse section. The large number of spores which the loculi still contain, is quite in keeping with what is seen in *Kaulfussia*, while the detachment of the whole synangium in one piece, which is specially noted by RENAULT, is also a point for suggestive comparison. In comparing the fossil with the modern genus RENAULT remarks that their synangia differ considerably; he notes the cup-like form of the synangium of *Kaulfussia*, and that the dehiscence is obliquely inwards, while in the fossil the synangium is not hollowed at the apex, and the dehiscence does not take place obliquely inwards, but is apical: moreover, the vascular tissue is extended even to the upper part of the synangium: he concludes, "it appears, therefore, that these fructifications were of a more complex structure than that of the living Marattiaceæ of the genus *Kaulfussia*." But the differences thus noted do not appear to me to be so great as they are deemed to be by RENAULT. A comparison of my fig. 32 shows that the cup-like depression of *Kaulfussia* is very slight when young, and even in the mature state (fig. 43) it is not so great as the often-quoted drawings in the 'Genera Filicum' (Plate 59A) would indicate. Secondly, as shown by fig. 43, the oblique inward direction of the slit is only slight. Again, we see in *Kaulfussia* that the vascular tissue is extended upwards into the synangium (fig. 42), though not so far as in *Pecopteris unita*, nor is it so coherent a strand. All these are differences of degree, not of kind, and involve characters which, on comparison with other living Marattiaceæ, we regard as of secondary importance. The conclusion which I draw is that there is a substantial and striking similarity between the sorus of this fossil and that of the modern *Kaulfussia*.

Another interesting genus of Marattiaceous fossils, with circular sori consisting of 3–6 sporangia, united in their lower part, and accordingly coming away in one piece, is that described by RENAULT (*loc. cit.*, pp. 11–19), under the name of *Diplolabis*. The walls of the sporangia at maturity are only one layer of cells in thickness, and there is no differentiated annulus. As regards the number of spores in each loculus seen in section, this fossil would accord with modern Marattiaceæ, but the correspondence in general characters is not specially close with any living genus.

The genus *Renaultia* created by STUR to receive the fossil described by RENAULT,* and ascribed by him† undoubtedly to the Marattiaceæ, includes a form of sorus which again combines characters in an interesting way. The sorus, consisting of five sporangia is of the uniseriate radiate type, with introrse dehiscence; the sporangia are united below upon a common receptacle, so that the whole sorus may come away in one piece. The peculiarity is the presence of a rudimentary apical annulus, which suggests an affinity with *Angiopteris;* but it would appear that though there are undoubted points of correspondence, the sporangium of *Renaultia* was a less massive one than that of *Angiopteris evecta;* a comparison of RENAULT's drawing* with my own drawing of the apex of the sporangium of *A. evecta*, fig. 76, demonstrates this. It is highly probable that *Renaultia* has Marattiaceous affinities; but it would appear that the sporangium is of a more attenuated type than that of any living Marattiaceous Fern.

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* 'Cours,' III., p. 122, Plate 22, figs. 9–11.

† STUR, *loc. cit.*, p. 760.

The genus *Hawlea* (CORDA)† shows a circular uniseriate, radial sorus of 3–6 sporangia, which are separate from one another, but seated on a short circular receptacle. They diverge radially from one another when mature, and dehisce by a radial introrse slit, which is directed obliquely upwards. STUR‡ describes a "rudimentary apical annulus," but it is not clearly shown in his figures. The character of the leaf is compared by him with that of *Marattia*. CORDA referred it to the Gleicheniaceæ; BERTRAND§ gives only partial assent to this, and STUR repudiates that affinity, both on ground of the form of the leaf and of the sporangium, the latter having no circular annulus. He assigns to it|| a middle position among living forms, recognising in the leaf a similarity to *Marattia*, in the circular form of the sorus to *Kaulfussia*, and in the details of the sporangium to *Angiopteris;* and this is probably its true position, though it would be accepted with greater confidence if the microscopic details were better known by a study of sections.

The genus *Oligocarpia* (GOEPPERT) has been the subject of some divergence of opinion, and offers certain points of considerable interest. The genus as founded by GOEPPERT, has been considerably extended by the observations of STUR.¶ The species first made known (*O. Gutbieri*, GOEPP.) has a uniseriate sorus of 3–5 sporangia; later described species show 6–7 sporangia, with one of these in a central position surrounded by the rest; these lead to the case of *O. Brongniarti* (STUR),** where there are usually seven sporangia, of which one is central; there are, however, others with as many as twelve sporangia, of which 8–9 are peripheral, and 2–3 occupy a central position. This arrangement of the sporangia finds no parallel among living Marattiaceæ, in which the sorus is always radiate and uniseriate, the central region being always unoccupied by sporangia. But in the genus *Gleichenia* the case can be exactly

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* *Loc. cit.*, Plate 22, fig. 9.

† STUR, *loc. cit.*, p. 681, &c.

‡ *Ibid.*, p. 684.

§ 'Cours,' III., p. 83.

|| *Loc. cit.*, p. 685.

¶ *Ibid.*, p. 687.

** *Ibid.*, p. 688, fig. 16.

matched. While most *Gleichenias* have a strictly uniseriate and radiate type of sorus, with relatively few sporangia, *Gleichenia dichotoma* (WILLD) shows a sorus with more sporangia, which are disposed in a peripheral series, with a variable number placed centrally. Sometimes there is a single central sporangium, sometimes two, three, or even four. STUR remarks* that in *Oligocarpia* the sori with most numerous sporangia are seated where nerves are so close together as not to allow space for development of the two sori individually; this is precisely what may be observed in *Gleichenia dichotoma.* It is certainly interesting to note this correspondence of the modern *Gleichenia* with the ancient *Oligocarpia,* and specially so since some authors† have referred the fossil to a Gleicheniaceous affinity. But it must not be assumed that the similarity of arrangement of the sorus will demonstrate an affinity in face of differences of detail of the sporangia. We shall therefore turn to the examination of the latter.

The sporangia are closely arranged on a relatively broad receptacle, and are of pear-like form, and quite separate from one another. The comparison with *Gleichenia* turns upon the presence of an annulus, and fissure-like dehiscence. As against the statement of ZEILLER‡ that a transverse annulus exists, as in the Gleicheniaceæ, SOLMS§ supports STUR's denial that such an annulus is to be seen, though the upper part appears to be occupied by strongly-thickened cells. Moreover STUR states that though he has examined hundreds of sporangia he has never seen one with a gaping dehiscence; he describes a terminal hole or depression, and compares this with the porous dehiscence of *Danæa.* While we reserve an opinion as to the correctness of this comparison till details are better known, the absence or at least the great rarity of dehiscence suggests the question: what use would there be for an annulus such as ZEILLER postulates if dehiscence by a slit does not take place? The view which I am disposed to entertain is that *Oligocarpia,* which is but incompletely known, is not necessarily to be ranked either with Marattiaceæ or with Gleicheniaceæ, but it is probably one of those intermediate forms, showing affinities with both, which on general grounds we should naturally expect to have existed. We know as yet of no other fern type with porous dehiscence of an exannulate free sporangium; these characters in themselves, if established, should suffice to indicate an independent position, though probably with Eusporangiate affinities.

And if such an uncertain view is to be entertained for *Oligocarpia,* much more will the element of uncertainty enter into discussions of other fossils attributed with more or less certainty to the Marattiaceæ, such as *Saccopteris, Discopteris,* &c. I do not think that any good morphological purpose can as yet be served by instituting strict comparisons of living forms with ferns known so imperfectly by impressions, and not by internal structure. Still *Saccopteris* (STUR) shows us a radiate though not simply uniseriate sorus, of separate sporangia, with oblique slit-like dehiscence; a type of which the pollen sacs of Cycads are suggested by STUR as the nearest living representatives. The number of sporangia in the sorus is about fifteen, but in *Discopteris* (STUR) the number of the free sporangia may be 70 to 100, in the sorus. Whether or not these ferns are rightly attributed to the Marattiaceæ (a matter on which I feel some doubt) they show at all events that ferns existed at the coal period, with sori not simply uniseriate, and composed of numerous relatively small free sporangia, which did not conform to the annulate Leptosporangiate type.

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* *Loc. cit.,* p. 689.

† ZEILLER, 'Ann. Sci. Nat.,' 6, XVI., pp. 190–192; RENAULT, 'Cours,' III., p. 67.

‡ *Loc. cit.,* p. 191–192.

§ 'Fossil Botany,' p. 146.

From examples such as those above noted, and they have been selected as those in which the details are best known, the similarity of the sori of certain early ferns to the modern Marattiaceæ is sufficiently clear. But while modern Marattiaceæ show differences of cohesion of the sporangia, this is still more obvious in the fossils, which range between the complete coherence of *Asterotheca*, and the entirely separate state of those of *Hawlea*. One striking feature which is shared by all the best known of these Marattiaceous types is the almost circular, rosette-like form of the sorus, but all the living genera show a more or less elongated form of sorus, while in *Danæa* the sorus is commonly much longer than broad. The question then arises as to the existence of fossil types having a similar form of sorus.

Under the names *Danæites* and *Danæopsis* certain ferns are described, which, so far as can be judged from a study of impressions, appear to conform to the *Danæa* type of sorus;[*] it is, however, an open question whether the relation of the sporangia to one another, and the mode of dehiscence, were exactly as in the modern *Danæas*. At least the ferns appear to be Marattiaceous, and have elongated sori. They are found in the Coal Measures, Keuper, and Lias.

On the other hand, there are certain fossils of probable Marattiaceous affinity, known from well-preserved specimens, which show a disposition of the sporangia with less clear definition of the sori. Among these may be cited STUR's *Grand' Eurya Renaulti* and *G. Autunensis*. In these STUR[†] specially notes the arrangement of the sporangia, and his use of the terms "general sorus" and "special sorus" is a consequence of their indefinite grouping: for the individual sorus does not seem here to be definitely circumscribed, though the sporangia are often grouped together by fours. This arrangement may find its nearest parallel in that of the pollen-sacs of certain modern Cycads.

Other early fossil ferns with a possible Marattiaceous affinity show even less definiteness of the sorus. Such is the case in the fragment named *Myriotheca* by ZEILLER,[‡] in which the whole lower surface of the pinnule is covered by sporangia,

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[*] See STUR, *loc. cit.*, p. 778; SOLMS, *loc. cit.*, p. 149. The earlier references to these fossils are quoted by these authors.

[†] *Loc. cit.*, p. 677, &c.

[‡] 'Ann. Sci. Nat.,' Ser. 6, vol. 16, p. 186.

without apparent order. ZEILLER'S description and figures point to a Marattiaceous affinity for this fern, in which case it would be to those Marattiaceæ with circumscribed sori, as *Acrostichum* is to most Polypodiaceous ferns. With such types that of *Senftenbergia* might also be compared, though the true affinity of this fossil may be questioned; here the large sporangia appear to be solitary.

We have so far considered cases where the sori are on the under surface of the leaf; there remain to be noted those fossil ferns of probable Eusporangiate affinity, in which the sori or sporangia are marginal. Prominently among these are *Grand' Eurya*, ZEILLER,* with its massive, apparently marginal sori, and the curious family of the Botryopterideæ, described by RENAULT.† Such fossils as *Calymmotheca* and *Crossotheca* have also marginal fructifications, but it is impossible in the present fragmentary state of our knowledge to make much use of these for purposes of comparison. One point at least they serve to illustrate—that whatever may have been the nature of their fructifications, they were seated in a marginal position, and the sporangia in certain of them were of size comparable to that of living Eusporangiate ferns.

From the fossils above cited it is plain that in the earlier fern flora there was a greater variety of position, and of detail in the fructifications, than in the Marattiaceæ of the present day. The latter illustrate one main type, upon which the four genera show certain variations. The fossil ferns, which we believe to have been more or less allied to them, were more varied. Nevertheless, there were among them certain plants which correspond in a remarkable degree, even in the details, with modern Marattiaceæ, and the most closely comparable types yet known are those in which the details are in best condition for microscopic study, viz., *Scolecopteris elegans* and *Pecopteris unita*.

THEORETICAL CONSIDERATIONS BASED UPON COMPARISON OF FOSSIL AND MODERN MARATTIACEÆ.

Certain theoretical questions may now be discussed on the basis of such data as have been collected in the preceding pages. But in so very ancient a family it will be readily believed that finality of opinion will be difficult to attain, and we can hardly look for actual demonstration; it will be necessary to be satisfied with a consideration of probabilities.

As regards the *distribution of the sori* on the sporophyll we note as facts of interest, among the fossils described as belonging to the Marattiaceæ, that in certain cases the sori appear not to be segregated (*Myriotheca*), in others they are not clearly defined (*Grand' Eurya*), while in all the living genera they are commonly isolated on the under surface of the leaf. But even here they are not always strictly defined, for they show occasional abstrictions. These facts plainly correspond to those well known in Leptosporangiate ferns; as in them, so here, it should be recognised that the circumscribed sorus is only the prevalent, not the exclusive type, while in the Marattiaceæ it is the fossils which supply the less definite examples. On the question of origin of the definite sorus, STUR (*loc. cit.*, p. 792), after remarking that types with solitary sporangia lived simultaneously with those in which sporangia are united into true sori, proceeds (p. 793) to state that "*Hapalopteris* is more recent than *Senftenbergia*," that is, "the species with solitary sporangia are older than those in which the sporangia appear gathered in irregular groups." I do not think that this can be accepted as a general statement of a morphological progression. It appears to be based upon observation of two genera only, important and early though they certainly are. Before it can be considered as established on palæontological grounds alone, the absence of ferns with clearly defined sori of prior date and of reasonably close affinity would need to be demonstrated; but it is to be remarked that various genera with definite sori (*e.g.*, *Oligocarpia*, *Saccopteris*) are recorded by STUR himself from the same strata as *Hapalopteris*, and even *Danæites*, which has a most compact and circumscribed type of sorus, is accepted by him as simultaneous with that genus. The question of time and mode of origin of the definite sorus would thus appear to be still an open one; the palæontological facts are not sufficient to justify a general statement on the point, in view specially of the fact that there is evidence of ferns with considerable variety of structure having existed at the time of the Culm and in the Devonian period.

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* 'Ann. Sci. Nat.,' Ser. 6, vol. 16, p. 303.

† 'Cours.,' III., p. 100, &c., originally described in 'Ann. Sci. Nat.,' Ser. 6, vol. 1, p. 220.

The *form of the sorus* in the Marattiaceæ when it is circumscribed, varies considerably, though, as above noted, its plan of construction is remarkably uniform, being of the radiate uniseriate type. It may be almost perfectly circular (*Asterotheca*, *Scolecopteris*), or more or less elongated (*Kaulfussia*, *Marattia*, *Angiopteris*), or elongated to a very considerable extent (*Danæa*, *Danæites*). It would appear that very much the same extreme variations of form of the sorus are found among the early fossil Marattiaceæ as in those of the present day: but there is not sufficient evidence to show on palæontological grounds how far the two types are related by descent, and if they be so, which type, the circular or the elongated, was the prior, and which the derivative; for both types appear in the lower Coal Measures, though *Saccopteris* with a circular sorus is believed to occur in the Culm. On comparative and developmental grounds, however, the question may be approached.

There is among the early fossil ferns a distinct prevalence of the type with sori arranged with regularity in a single row on either side of the midrib of the leaf-segment, an arrangement which is maintained in our modern *Gleichenias*, in *Angiopteris*, *Marattia*, and *Danæa* (with occasional exceptions), but not in *Kaulfussia*. In many of the fossils the form of the sorus is circular, and the number of sporangia small (*Scolecopteris*, *Asterotheca*, *Hawlea*, *Oligocarpia*); and partly on the ground of its early prevalence, partly on developmental grounds which will be explained in connection with the details of septation, I think it reasonable to regard the circular sorus with few sporangia as a central type from which others were derived, especially such an extreme condition as that seen in *Danæa*, though it is to be remembered that this type is recorded so early as the Carboniferous period. But whatever view may be taken on this point, the extremes are connected by intermediate examples, and it is no difficult matter to see that a slight modification of a pinna with circular sori, by extension of the sori along the veins, might result in a type like *Danæa*, while in *Danæa* itself, the sori when abstricted (fig. 1) take a form very much like that normal for *Kaulfussia*. The instability of form in the individual serves thus to connect the more divergent types; it suggests that the condition in *Kaulfussia*, where the numerous circular sori are spread over a large leaf-area, may have arisen by extreme lateral extension of the wings of the pinna, accompanied by repeated abstriction of the sori during the process, after the manner shown in *Danæa* in fig. 1, *a*, *b*, *c*: signs of such abstriction are still to be seen in *Kaulfussia* as shown in fig. 31. Such extension of sori following on the broader development of the leaf, will harmonise with the facts stated by ZEILLER ('Bassin Houiller et Permien d'Autun,' pp. 23–4, also pp. 57–8), in the case of *Pecopteris densifolia* (GOEPPERT), *Grand' Eurya Autunensis* (STUR), and *Pecopteris Platoni* (GRAND' EURY) (*loc. cit.*, pp. 3 and 53, and plate 8, fig. 7). If a widening of the pinnule were followed by an extension of the sori and their final abstriction, just such difficulties in definition of the individual sorus as he mentions in the former species would probably present themselves. Accordingly, while admitting that the matter is not susceptible of present proof, my own opinion is that in *Danæa* and *Kaulfussia*, which are the extreme examples of extension of leaf-area, while the leaves themselves are simply pinnate, or even unbranched (*D. simplicifolia*), extension was accompanied in the former genus by elongation of the individual sorus, in the latter by abstriction of sori, and that both were derived from the circular type of sorus so prevalent in early times, as exemplified by *Asterotheca* or *Scolecopteris*; *Marattia* and *Angiopteris*, with their slightly elongated sori, would occupy a middle position. It will be shown that the facts relating to irregular and partial septations in the Marattiaceous sorus will accord with these views.

A further point for discussion is the *relation of the sporangia to one another in the sorus.* Among fossil and modern *Marattiaceæ* various gradations may be seen between such as have their sporangia quite separate, and those in which they are united from base to apex. Certain of those best known may be placed in series as follows, starting from those with separate sporangia:—*Hawlea*, *Angiopteris*, *Scolecopteris*, *Asterotheca*, *Kaulfussia*, *Danæa*. Without for a moment suggesting that such plants as those named ever constituted an evolutionary sequence, they at least show, within the limits of the Marattiaceæ, steps between the condition with separate sporangia, which is common for all Leptosporangiate ferns, and that synangial state which is one of the most marked characters of certain Marattiaceæ—

a peculiarity which they share, however, with various other Pteridophytes. It will be necessary, then, to consider upon all the evidence, whether the synangial state was the more primitive, or whether it resulted from the coalescence of parts originally distinct.

The latter view has been commonly held by writers on the subject, but more often, perhaps, as an assumption following from the belief that the Leptosporangiate ferns with their separate sporangia, were the more primitive, than as the result of comparative and developmental study; this opinion is reflected with varying distinctness in the works of the earlier descriptive writers, by the use of such terms as "synangia," composed of "connate sporangia," &c. As long as it is held that the Leptosporangiates are a relatively primitive type, and that the Marattiaceæ, if not themselves derived from them, must have their morphology explained from the Leptosporangiate point of view, the assumption that their synangia are a result of fusion is a convenient, if not even a necessary consequence. But in recent years the relatively primitive character of the Eusporangiate ferns has been repeatedly insisted upon,* and I think the present position should be that they are to be taken on their own merits, and their morphology discussed independently of any question whether or not the results arrived at will harmonise with views as to descent from any Leptosporangiate ancestry.

In his paper on the development of the sorus of *Marattia*, LUERSSEN (1872), upheld, as against the prevalent theory of coalescence, that the sorus of *Marattia* is really a multilocular sporangium ("vielfächeriges Sporangium"), and not a sorus. He rejects (*loc. cit.*, p. 4) the analogy of *Angiopteris*, remarking: "It is not clear why the organ of fructification of *Marattia* should be looked upon as a 'sorus,' and the single loculi as 'sporangia.' To do so only on account of the analogy with the genus *Angiopteris*—leaving out of account the rest of the ferns—does not seem advisable." LUERSSEN was evidently struck by the probability of septation as accounting for the condition of the sorus of *Marattia*, and it will be seen that his view of the sorus as a single partitioned body, rather than a body resulting from the fusion of sporangia originally distinct, has some affinity with the opinions expressed below; but it is necessary that I should at once dissociate my own views from his as regards the comparison with *Angiopteris*: the error which he made, was in underrating the true similarity of the sorus in those obviously related ferns. And subsequent writers were not slow to take up this point. In SACHS's 'Lehrbuch,' which reflects so admirably the current botanical opinion up to 1874, it is stated (p. 413) that the analogy with *Angiopteris* "clearly determines that in *Marattia* we have not to deal with a plurilocular sporangium, but with a sorus of which the single sporangia have fused one with another." Fresh developmental work was used as evidence in the same direction, and GOEBEL ('Bot. Zeit.,' 1881, p. 685) remarks that "It is hardly necessary to state again that the fused sporangia of *Marattia* are a sorus, and not, as they had sometimes been held to be, a plurilocular sporangium; this follows from the fact that each sporangium, as in *Angiopteris*, has its own special archesporium."

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* CAMPBELL, 'Bot. Gazette,' January, 1890. BOWER, 'Annals of Botany,' vol. 5, p. 109. CAMPBELL, 'Mosses and Ferns,' p. 302, &c.

We shall naturally accept the position that what is usually styled the sorus in *Marattia* is a true sorus, comparable with that of *Angiopteris*, and of various other ferns; but the further point included in the above quotation from GOEBEL does not necessarily follow. Even if the fact were always as he states, that each sporangium has its own special archesporium, this does not by any means prove that it was separate by descent from its neighbours. And it has been shown above that, as a matter of fact, occasionally in *Marattia*, and much more frequently in *Danæa*, each sporangium has not always its own distinct archesporium. Moreover, while using developmental evidence, little account has been taken by other writers of the structure of the septa which separate the loculi; whereas their variable thickness and occasional incompleteness are matters very material to the question before us. It will thus be seen that the real nature of the sorus, and its mode of origin by descent, cannot be settled simply by brief allusion to the usually separate archesporia; as regards the developmental evidence, the question must be considered as still an open one.

STUR, having in view chiefly the data derived from the study of fossils, has also expressed his opinion as to the relative time of origin of the synangial condition in certain Marattiaceæ.* Having summarised into a table† those fossils of the Culm, Coal Measures, and present periods, which he attributes to the Marattiaceæ, he argues on the point in question from the data in the table as follows‡:—

"*Danæites* and *Oligocarpia*, both with sporangia dehiscing at the apex, are present alike in the lower Coal Measures (Unter-Carbon), while *Saccopteris* with sporangia resembling pollen sacs dehiscing at the apex, is believed to have existed in the Culm (" schon im Culm zu vermuthen ist"). Accordingly the flask shaped coalescent§ (*sic*) sporangium would be earlier, having appeared at the time of the Culm, while its coalescence first appeared in *Danæites* in the lower Coal Measures (Unter-Carbon)."

"Accordingly the *coalescence* of sporangia to a star-shaped (*Scolecopteris*) or linear (*Danæites*) sorus was more recent than the first appearance of the correlative non-coalescent sporangia."

"The types of *Senftenbergia* in the Culm, of *Scolecopteris* and *Renaultia* in the upper Coal-Measures (Ober-Carbon), and of *Marattia* at the present time, indicate three different stages of the Marattiaceous fructification attained by modification."

From the above quotations it is plain that STUR contemplated a progressive coalescence of sporangia to form synangia, and read the palæophytological record as establishing this opinion. I do not think that this conclusion is sufficiently justified by the facts. We may put aside *Senftenbergia* on the double ground that its affinity with the Marattiaceæ is uncertain, and that, its sporangia being isolated, and not associated into sori, it cannot be used in argument as to the progressive changes within the sorus itself at that early period. The argument of STUR as to the later appearance of coalescence of sporangia within the sorus, turns then upon the case of *Saccopteris;* but even STUR himself does not go further than saying that this plant is believed to have existed in the Culm ("im Culm zu vermuthen ist"): it is present, certainly, he states, in the lower Coal Measures; but he admits that *Danæites* is also present in the lower Coal Measures, and that is a type in which the synangial condition is seen in its most pronounced form. So that, as far as there is really secure evidence from forms admitted to be Marattiaceous, it would seem that the geological record shows a simultaneous appearance of the two types in the lower Coal Measures, and therefore will not serve to decide the priority either of those with sporangia distinct in the sorus, or with the sporangia united in a synangium.

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* 'Sitz. d. Wien. Akad.,' 1883, Abth. 1, p. 633, &c.

† STUR, *loc. cit.*, p. 791.

‡ *Loc. cit.*, p. 793.

§ The word "verwachsene" in the text must, I think, be a mistake for "unverwachsene," for *Saccopteris*, to which it is applied, has non-coalescent, separate sporangia.

In this connection the recently expressed opinion of RENAULT is of especial interest ('Gîtes Mineraux,' vol. 4, p. 5). Speaking of the true "*Pecopteris,*" by which name he designates those with "sporangia grouped in a sorus," he remarks that "hitherto the true *Pecopteris* appeared peculiar to the upper Coal Measures, we therefore think it interesting to indicate their presence in the quartzes of Esnost; these quartzes enclose, as is known, the remains of *Bornia,* of stems and branches of *Lepidodendron,* the anthracites which accompany them have yielded impressions of *Cardiopteris,* and of *Bornia;* all this leads to the supposition that they belonged to an epoch much more ancient than that of the upper Coal Measures, for instance, to the Culm."

The last passage above quoted from STUR, in which he selects *Senftenbergia, Scolecopteris, Renaultia,* and *Marattia,* as indicating stages in the progress of the Marattiaceous sorus, cannot be accepted as cogent, when it is remembered that *Senftenbergia* is of doubtful affinity, and that *Danæites* with its synangial sorus is recorded from older strata than any of the other three. My own opinion is that, even without urging strongly the inherent weakness of negative evidence, which would lay stress on the fact that certain types are not yet recorded from certain strata, the question of the time and mode of origin of the synangial sori cannot be settled on the ground of present palæophytological knowledge; as regards the facts available from the study of fossils the question should be regarded as still open.

The most that can be said with certainty is that the earliest ferns of which the sporangia are at all accurately known have separate sporangia; but on the other hand, both the type with coalescent sporangia, and that with separate sporangia associated in a sorus, are very ancient, and have been recognised as having existed already in Marattiaceous ferns from the lower Coal Measures. In arriving at these conclusions I do not ignore the possibility that ferns interesting for comparison, or even of truly Marattiaceous character, may have existed earlier. I would on the contrary suppose that very important links in the chain of evolution existed before those taken by **Stur** as the basis of his argument. It is true that *Senftenbergia* is recorded from earlier rocks than well authenticated Marattiaceæ; but its affinities seem to be with the Schizæaceæ rather than the Marattiaceæ. In the fact that it is perhaps the earliest recorded fern in which the details of the sporangia are well enough preserved to form a basis for comparison, I see no sufficient reason for regarding it as a Marattiaceous ancestor, or even as representing a condition ever passed through in the evolution of the Marattiaceæ. Moreover, it is not the earliest known fern; those of the Devonian period have also to be remembered, while in the Culm there is evidence of a considerable and varied fern flora; this has been brought into prominence afresh by **Solms-Laubach**'s recent revision of the fossil plants described by **Unger** from the Unter-Culm ('Abhandl. d. k. Pr. Geol. Landesanstalt,' Neue Folge, part 23). The variety of structure of fern petioles there described is considerable; it is reasonable to suppose that this variety of vegetative structure was accompanied by variety of the sorus, and it should at least be a warning against generalisation in such a case as this from few facts. It is quite possible that the differentiation both of synangial sori, and of those with separate sporangia, either grouped in sori or solitary, may have been of much earlier date than those used as the basis of his argument by **Stur**.

Another consideration will make the conclusion of **Stur** seem questionable; perhaps no feature in the Marattiaceæ is more remarkable than the persistence of type from the remote past to the present day. **Stur** himself points this out (*loc. cit.*, p. 796). Are we to believe that this type which has virtually stood still through so many successive geological periods, was so quickly plastic at the Carboniferous period as to show a progression from a type with entirely separate sporangia, as seen in *Senftenbergia*, to the completely synangial condition seen in *Danæites*, between the Culm and the lower Coal Measures? I think such a suggestion is improbable, though, of course, it is not impossible.

Accordingly, whether we discuss the form of the Marattiaceous sorus, or the relations of the sporangia composing it, it appears desirable to return to comparative and developmental considerations derived from living Marattiaceæ, and see how far the facts detailed above may serve as a basis for views such as shall not be incompatible with the fossil evidence.

It cannot fail to strike even a superficial observer how great is the similarity of the sorus of *Danæa* to the fertile spike in *Ophioglossum*. Notwithstanding that the former is applied throughout its length to the lower surface of the leaf, while the latter is a body which rises free and erect from the upper, still they resemble one another in being composed essentially of two parallel rows of laterally flattened sporangia, which are of approximately uniform size, project only slightly at the surface, are separated from one another by septa of variable thickness, and produce numerous homosporous spores. The difference of position of the two bodies would be sufficient to preclude any suggestion of homology; but as I have elsewhere explained, the mere search after homologies is not the main feature in our morphological study: it is a matter of deeper interest to inquire after the probable method by which parts so different in position, but so similar in structure and function as the spike of *Ophioglossum* and the sorus of *Danæa*, may have come into existence.

In a former Memoir (Studies II., Ophioglossaceæ) I have discussed the morphology of the spike of *Ophioglossum*, and found that the details of development are compatible with a view of its origin by septation from a simpler non-septate body. It was seen, moreover, that such a process of septation, producing somewhat similar results, has occurred not uncommonly in the Anthers of Angiosperms. Comparative evidence was also adduced which supported the view of septation for *Ophioglossum*. Having thus the analogy of anthers of Angiosperms, and (on my view) that of the spike of *Ophioglossum* before us, it may be inquired what bearing the developmental facts have upon the origin of the sorus in *Danæa;* do they support a theory of fusion or of septation as explaining the present structure?

It has been seen that in the synangial genera of Marattiaceæ a "superficial parent cell" commonly gives rise to the sporogenous group, together with the cap of tissue covering it, while a band of tissue, which develops into the septum together with the tapetal layer on either side of it, separates the sporogenous groups one from another. Such a structure of the young synangium would be compatible either with a view of progressive septation or of sporangial fusion, if the septa were of uniform thickness, and the archesporia all distinct from one another. GOEBEL has already used the developmental evidence in favour of the theory of fusion, assuming, in accordance with his own observations on *Marattia*, that there is this uniformity.

But it has been a matter of special description and remark in the above pages, that in *Danæa* there are palpable departures from regularity, also though less commonly in *Marattia* and *Kaulfussia*, and occasionally in *Angiopteris*. The chief points material to the present question are the following :—

(1.) The great variability of size and shape of the single loculus. A glance at fig. 20, or fig. 58 shows this very clearly; or if the comparison be based upon enumeration of the sporogenous cells, the extreme cases shown in fig. 11, which were drawn from the same leaf and are of similar age, may be quoted; extreme variability of the loculi is seen at the ends of the sori in *Danæa* (fig. 13). Such differences are certainly rare in ferns with separate sporangia, and would not be probable if the synangium were the result simply of lateral fusion of such sporangia. A special interest attaches to those cases where the sporogenous group is not referable to a single parent cell; it is difficult, on a view of coalescence of sporangia, to understand how such a condition would have come into existence.

(2.) The occurrence of incomplete septa, and of sporangia in equal pairs suggesting a process of septation, is a feature which is by no means uncommon in *Danæa* (fig. 20), especially where the sori are long; it occurs also, though less frequently, in *Kaulfussia* and *Marattia*, but is rare in *Angiopteris*. It may, therefore, be taken to be a special feature of the synangial forms, and is most prominent when the sori are longest. This is a point of the greatest importance as bearing on the theory of the sorus.

(3.) Closely connected with the occurrence of incomplete septa is their variable thickness, and this has been described in detail. From the usual septum, consisting of some two or three layers of permanent tissue, with transitory layers of tapetum on either side, all gradations of thinning off of the septum may be found in *Danæa*, to the condition of a simple tapetal layer (fig. 28), and even onwards to the mere encroachment of tapetal cells into the simple sporogenous group.

(4.) The occasional development in *Danæa* of cells outside the definite sporogenous group as fertile cells (fig. 21), and conversely of cells of the sporogenous group as sterile cells (figs. 22, 23), shows that the fertile tissue is not so strictly defined in this genus as it is usually found to be in other ferns.

Now it is possible to read these facts as consistent with either a view of progressive coalescence of sporangia originally separate, or of a progressive septation of a less completely septate sorus. If the former view be taken, then the sorus of *Danæa*, which shows the features mentioned more commonly than other genera, would be held to have been descended from a type with sori even more elongated than those of the present day. But *Danæa* is the genus of Marattiaceæ which has the longest sori known in the family. I am not aware that any genus of Eusporangiate ferns, fossil or modern, has been described with sori longer than *Danæa*, and with separate sporangia. In the absence of evidence that any such supposititious ancestor ever existed, the view that the above phenomena in the sorus of *Danæa* imply coalescence of sporangia previously distinct appears to me to be without proper foundation.

But if we contemplate the converse view, that the characters described are evidence of septation of a body originally of less complex structure, some important considerations may be brought forward in support of it. *Danæa* is a broad-leaved type; the outline of its sori, which are the longest in the family, suggest that they have followed the broadening of the leaf or pinna, and that they are the result of extension rather than contraction. If derived from some average Marattiaceous type, with less elongated synangial sori (such as is represented in early rocks by *Asterotheca* or *Pecopteris unita*), an increase of septation as the sorus elongated would be a physiological advantage, if not even a necessity. There is thus a reasonableness in the suggestion that the present condition of the sorus has been the result of progressive septation, following on elongation of the sorus. Strong support of this is to be found in the analogy of septate anthers of certain Angiosperms, which show a close structural parallel to the details described for the sorus of *Danæa*. I have elsewhere dealt with septate anthers,* and it cannot be doubted, I think, for those genera of Onagraceæ in which the anthers are septate, that they were derived by septation from the ordinary Angiospermic type, the anthers, for instance, of *Gaura*, *Clarkia*, and *Eucharidium* being in other respects normal. But in these not only are the loculi of unequal size, as are the sporangia of *Danæa*, but the septa also vary in thickness, being sometimes composed of a band of permanent tissue with tapetum on either side [compare fig. 15 of *Danæa* with fig. 54 (Plate 4, *loc. cit.*) of *Clarkia*]; sometimes they are thinner, and may even consist of only a single layer of tapetum [compare fig. 28 of *Danæa* with fig. 53 (Plate 4, *loc. cit.*) of *Gaura*]. Moreover, in the mature anther of various Angiosperms, which show such septations, partial septa similar to those of *Danæa* may be seen. I do not think that these are merely fortuitous resemblances; it seems much more probable that this similarity of detail, in plants so far apart systematically, is a consequence of a similar morphological advance, in either case by subdivision of loculi previously less completely septate. The analogy of the septate anthers of Angiosperms shows, in any case, that the similar details of structure in *Danæa* are consistent with a theory of progressive septation of the sorus; this again is in accord with the results of comparison with other Marattiaceæ, on which ground it seems probable that the sorus of *Danæa* has been subject to elongation.

Partial septa are also found in *Kaulfussia* and *Marattia*, though less commonly. These are genera with slightly elongated sori, and if they have been derived from a type with a circular form of sorus, such as that of *Asterotheca*, the partial septations might be regarded as related to the elongation of the sorus, just as in *Danæa*, though in a less prominent degree.

The facts and arguments contained in the above pages are not put forward as leading to any definite demonstration as to the mode of origin of the Marattiaceous sorus, or as to the relations by descent of any of its various types. The contention which I do press, however, with some persistence, is that these questions are still open, notwithstanding that writers of authority have treated them as already decided, whether by evidence from fossils, or from development of living forms. I have above pointed out how in my opinion the palæophytological evidence is insufficient to prove the priority in the Marattiaceæ either of the type with separate sporangia, or of the synangial type. As far as I can see, the facts from fossils would be consistent with either view. Nor does the argument from comparison and development of living forms lead to any definite conclusion, so long as we treat the Marattiaceæ on their own merits, and do not proceed on the assumption that they were descended from Leptosporangiate ferns. Comparing them, *inter se*, it would be *possible* to interpret all the facts as consistent either with a progression from a synangial state to sori with separate sporangia, or as consistent with a progressive coalescence. This conclusion will I think be admitted by those who follow all the details above described, and I consider it to be the most important result of this investigation.

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* 'Studies,' II., pp. 1–6.

But it is our duty not only to contemplate *possible* views, but to decide which is, in our own opinion, the more *probable*. Having in view, in addition to the facts from palæontology and from the study of development, the comparison with other Pteridophyta and the facts from septate anthers of Angiosperms, it seems to me probable that a progressive septation has taken place in certain types of Marattiaceæ, where the sori are elongated, such as *Danæa*, and in a less degree *Marattia* and *Kaulfussia*. It may be a question how far a similar septation may be accountable for the origin in the first instance of a sorus with a plurality of sporangia united together, as in *Asterotheca*, though I think this not improbably the mode of their origin. I am disposed to regard such synangial types as being probably the more primitive, and to think that a progressive separation of the individual sporangia has led from these to such a type as *Angiopteris* or *Hawlea*. This view is at least consistent with the facts, so far as I understand them, though it is not put forward as in any way demonstrated. A full discussion of this matter will, however, be deferred for the present; it will find its best place when the Leptosporangiate ferns have been examined, and it is to them that the next part of these Studies will be largely devoted, while it will also include a discussion of the morphology of the spore-producing members of Pteridophytes at large.

Certain of the facts brought forward in this Memoir have a general bearing. It follows from the occurrence of partial septa, and of gradual steps in septation, that in the cases where this occurs the identity of the individual sporangium is not maintained. Seeing, in the Leptosporangiate ferns, the wonderful specialisation of the sporangium, and the regularity of its segmentation, the mind is disposed to accord to it a definite individuality; but this is only a character of this highly-specialised series, and is in itself one of the most clear marks of their specialisation. In such a leaf as that illustrated in fig. 30, the identity of the single sporangium seems quite lost, and it may be left as an interesting matter for reflection whether or not such a condition is to be considered as more primitive than the highly-individualised sporangia of a *Polypodium*.

Again, it is a matter of general interest to note any further example of the want of a definite limit of sporogenous tissue. In *Danæa* each sporogenous group is commonly derived from a single parent cell, and forms a clearly-defined body of cells, but, occasionally, a cell-packet outside the definite group becomes sporogenous (fig. 21), while conversely, certain cells of the definite group do not develop as spores, but as tapetum (figs. 22, 23, 26, 27). Such cases show, as has already been remarked elsewhere,* that the limits of spore-producing tissues are not constant in the individual plant, and that normally vegetative tissues may at times be sporogenous, and normally sporogenous tissues may be diverted to a vegetative function.

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* 'Phil. Trans.,' B, 1894, p. 553.

DESCRIPTION OF FIGURES.

Danæa. Figs. 1–30.

PLATE 7.

Fig. 1. *Danæa alata* (SMITH). *a*, a fertile pinna, with many normal sori; the arrow indicates an abnormal fission. *b*, *c*, show more numerous abnormal fissions, resulting in irregularly-formed sori distributed over a slightly enlarged leaf-surface. (× 2.)

Fig. 2. *D. elliptica* (SMITH). Vertical section through two sori (*s*). *i* = indusium, *v.b.* = vascular bundle. (× 10.)

Fig. 3. Ditto, tangential section of sporophyll, traversing parts of three sori. (× 10.)

Fig. 4. Ditto, section traversing one sorus longitudinally. (× 10.)

Fig. 5. Ditto, a similar section, showing partial septa. (× 10.)

Fig. 6. Ditto, vertical longitudinal section of a young sorus, showing three loculi, with various segmentation. (× 150.)

Fig. 7. Ditto, similar loculi, illustrating extremes of variability of size and segmentation. (× 150.)

Fig. 8. Ditto, an unusually large loculus, with somewhat irregular relation of the surrounding tissue as regards segmentation. (× 150.)

Fig. 9. Ditto, with very regular segmentation. (× 150.)

Fig. 10. Ditto, tangential section, traversing a sorus, and again showing irregularity of the segmentation. (× 150.)

Fig. 11. Ditto, extreme cases of variability of form and segmentation of sporogenous groups, all taken from the same leaf. (× 150.)

Fig. 12. Ditto, vertical section through a typically regular sorus. (× 150.)

Fig. 13. Ditto, tangential section traversing the end of a sorus, and showing the irregular form of a terminal loculus. (× 150.)

Fig. 14. *Danæa alata* (SMITH). Vertical section through a rather older loculus, showing unusually regular segmentation. The number of cells of the sporogenous group traversed is 108. (× 150.)

Fig. 15. *D. elliptica.* Tangential section traversing a sorus of very regular segmentation, and older than that shown in fig. 10. (× 150.)

Fig. 16. Ditto, tangential section traversing the superficial tissue of a sorus, and showing the regions of future dehiscence. (× 150.)

Fig. 17. *D. alata.* Vertical section through apex of a loculus prior to dehiscence. (× 150.)

Fig. 18. Ditto, at the time of dehiscence. (× 150.)

Fig. 19. *D. elliptica.* Pores of dehiscence, as seen from above. (× 150.)

Figures illustrating Partial Septations.

Fig. 20. *D. elliptica.* Tangential section through three sori, showing the loculi in ground plan. There is great variety in the size and form of these, and in the thickness of the septa. The latter are often thin, so that pairs of loculi are in close juxtaposition. The loculi marked with crosses are of unusual size, and show one or more partial septations. (× 20.)

Fig. 21. *D. alata.* Part of a sporangium, with the sporogenous cells deeply, and the tapetum lightly, shaded; one packet of sporogenous cells is seen extending beyond the general limits of the group. (× 150.)

Fig. 22. *D. elliptica.* Part of a loculus, showing one cell (*st*) developing as a large sterile cell, though it is evidently a sister-cell of the sporogenous cells. (× 150.)

Fig. 23. Ditto, another clear example of the same. (× 150.)

Fig. 24. Ditto, the tapetal cells appear to have encroached, as rounded sacs, upon the sporogenous mass. (× 150.)

PLATE 8.

Fig. 25, *a*, *b*, *c*, *d*. Ditto, in some cases it is doubtful whether the sterile cells are the result of encroachment or of conversion of sporogenous cells. (× 150.)

Fig. 26. Ditto, a large loculus, showing a median constriction, opposite to which the cells marked (?) show intermediate characters between tapetum and true sporogenous cells. (× 150.)

Fig. 27. Ditto, a very large loculus, showing two similar constrictions, indicative of partial septation into three. (× 150.)

Fig. 28. Ditto, a bridge of tapetal cells which extended completely across a loculus, forming a temporary septum. (× 150.)

Fig. 29. Ditto, a broader bridge of tapetal cells, with a partial septum of permanent tissue within, the cells of the latter being indicated by heavier lines. (× 150.)

Fig. 30. Ditto, three loculi, with septa; that between *b* and *c* is a permanent septum of the normal type; that between *a* and *b* is a temporary septum of tapetal cells, with only a very slight encroachment of permanent tissue, indicated by heavier walls. (× 150.)

Kaulfussia æsculifolia (Blume). Figs. 31–44.

Fig. 31. Sori of *Kaulfussia*, showing states of partial to complete abstriction; *f*, *g*, are seen from below; *st* is the common stalk of the double sorus.

Fig. 32. Young condition of the sorus, which is but slightly raised above the surface of the leaf, as seen in vertical section; the position of the two sporangia is indicated by shading. (× 20.)

Fig. 33. Part of a similar section on a larger scale, showing a sporogenous group (shaded). (× 150.)

Fig. 34. Ditto, more advanced. (× 150.)

Fig. 35. Ditto, still further developed. (× 150.)

Fig. 36. Ditto, the apex of the sporangium is now overarched by the more active surrounding tissue, the section having traversed the slit-like dimple, at the base of which the sporangium lies. (× 150.)

Fig. 37. Transverse section through a sorus traversing four young sporogenous groups. (× 150.)

Fig. 38. Similar section of part of an older sorus. (× 150.)

Fig. 39. Tangential section (such as along the line *x*, *x*, fig. 34), traversing two sporogenous groups, and illustrating the similarity of origin of the sporogenous groups, and of the septum. (× 150.)

Fig. 40. The slit-like dimple shown in tangential section is very narrow. (× 150.)

Fig. 41. The slit-like dimple in transverse section. (× 150.)

Fig. 42. Extension of irregular tracheides from the vascular bundle upwards into the base of the sorus. (× 150.)

PLATE 9.

Fig. 43. Vertical section of mature sorus. (× 20.)

Fig. 44. Ground plan of mature sorus. (× 20.)

Marattia fraxinea (Smith). Figs. 45–64.

Fig. 45. Very young sorus in vertical section. (× 300.)

Fig. 46. Ditto, older. (× 300.) Compare line of section *a*, *a*, in fig. 47.

Fig. 47. Tangential section, showing a sorus of the same age as fig. 46, in ground plan. (× 300.)

Fig. 48. A section through the young sorus corresponding to the line *b*, *b*, in fig. 47. (× 300.)

Fig. 49. Vertical section of rather older sorus (× 300), sporogenous group shaded.

Figs. 50, 51. Ditto, still further advanced. (× 300.)

Figs. 52, 53. Transverse sections showing the common type of sporangium of age corresponding to fig. 51.

Fig. 54. Transverse section rather older. (× 300.)

Figs. 55, 56, 57. Sections radial, tangential and transverse through a sporangium with sporogenous group ready to undergo separation, and tetrad division of the sporogenous cells. (× 150.)

PLATE 10.

Fig. 58. Three sporangia of similar age to the above, showing how variable the size, form, and segmentation of the sporogenous groups may be. (× 300.)

Figs. 59, 60. Outlines of other sporogenous groups. (× 300.)

Figs. 61, 62. Examples of sporogenous groups which appear referable in origin to more than a single parent cell. (× 300.)

Fig. 63. Unusually large sporangium, showing ingrowth of tapetal cells, so as to encroach largely upon the sporogenous tissue. (× 150.)

Fig. 64. Partial septation of a sporangium; the tapetal septum is complete, but there is only a slight indication of encroachment of permanent tissue on the loculus. Compare figs. 29, 30 of *Danæa.* (× 150.)

Angiopteris evecta (HOFFM.). Figs. 65–81.

Fig. 65. Part of a young sorus, seen in surface view from without. (× 300.)

Fig. 66. Vertical (radial) section of a sporangium, such as would be seen on cutting the sporangium (b) of fig. 65, along a line x, x. (× 300.)

Fig. 67. Tangential section through a similar sporangium. (× 300.)

Fig. 68. An older sporangium in vertical (radial) section. (× 300.)

Fig. 69. Transverse section of a similar sporangium along the line x, x, in fig. 68. (× 300.)

Fig. 70. Tangential section of a rather bulky sporangium showing such structure as might be seen if fig. 68 were cut in a plane y, y. (× 300.)

PLATE 11.

Fig. 71. Vertical (radial) section of an older sporangium, which still shows the genetic grouping of the cells. (× 300.)

Fig. 72. A similar section of an older sporangium. (× 300.)

Fig. 73. Transverse section of a similar sporangium, such as along a line z, z, in fig. 72. (× 300.)

Fig. 74. Tangential section of a similar sporangium, such as along a line y, y, in fig. 72. (× 300.)

Fig. 75. Apical region of an almost mature sporangium in tangential section, showing the thin-walled cells which define the line of dehiscence. (× 300.)

Fig. 76. Apex of an almost mature sporangium, seen from above; such a section as along the line x, x, in fig. 72. (× 150.)

Fig. 77. Transverse section of an almost mature sporangium. (× 300.)

Fig. 78. a, b, c, irregularities of sori. (× 35.)

Figs. 79, 80, 81. Sporangia from the same pinnule, cut transversely. Fig. 79 is normal. Figs. 80, 81 show very large sporangia, with indications of a partial septation in fig. 81. (× 300.)

III. *On the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.*—II. *On* Spencerites, *a new genus of Lycopodiaceous Cones from the Coal Measures, founded on the* Lepidodendron Spenceri *of* WILLIAMSON.

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[PLATES 12–15.]

INTRODUCTION.

THE fossils which form the subject of the present paper are Cryptogamic strobili showing evident Lycopodiaceous affinities, but differing in important points from other fructifications of that family, so that it appears necessary to establish a new genus for their reception. The specimens are derived from the Coal-measures of Lancashire and Yorkshire, and are calcified, the internal structure being thus preserved in considerable perfection.

As our present knowledge of the forms in question is entirely due to the researches of the late Professor W. C. WILLIAMSON, it will be necessary to give a short historical summary of the results which he attained, before going on to my own observations.

The first specimen described by WILLIAMSON* was a strobilus, of which he received sections from Mr. SPENCER and Mr. BINNS, of Halifax. From this material he gained a general idea of the structure of the axis, and showed that the sporangiophores are spirally arranged, and of peltate form, each bearing a single sporangium on its upper surface. He pointed out the peculiarities of the sporangial wall, in which this fossil differs from typical *Lepidostrobi*, and described in great detail the form and structure of the remarkable winged spores, as to the true nature of which he was in much doubt. It is unnecessary to follow his arguments in detail, but it may be mentioned that he had at that time already detected the minute spore-like bodies which sometimes occur inside the large spores, and that he interpreted the wings of the latter as consisting of their barren sister-cells, a view which no longer appears to be tenable.†

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* "Organization of the Fossil Plants of the Coal Measures," Part IX., 'Phil. Trans.,' 1878. Read in 1877.

† *Loc. cit.* pp. 340–344, Plate 22, figs. 38–47 and 52–57.

At that time **WILLIAMSON** called the cone merely a *Lepidostrobus*, without giving it any specific name, though he quite recognised its peculiar characters.

In his next memoir,* the author described a second specimen of the strobilus, of which he had received two transverse sections, also from Mr. **SPENCER**. He was thus enabled to give a fuller account of the anatomy than before, and to show that it possessed a "generally Lycopodiaceous aspect." He points out, however, that we do not see in this cone "any traces of transverse sections of" the leaf-trace bundles "grouped around the vascular axis, such as constitute so striking a feature of true *Lepidostrobi*." He emphasizes the "very distinctive individuality" of the strobilus, and names it *Lepidostrobus insignis*. This name, therefore, has priority, as the first given to the species.†

Ten years later, in 1889, **WILLIAMSON**, in his 16th Memoir, described specimens from Mr. **SPENCER**, of a supposed vegetative stem, to which he gave the name of *Lepidodendron Spenceri*.‡ The anatomical features are described and figured, and attention is especially called to the occurrence of partially-developed tracheæ in the middle of the woody axis, thus proving its centripetal development. The author overlooked the remains of foliar organs, the bases of which are often visible in these specimens, and was under the mistaken impression that the outermost cortex had perished, which is certainly not the case. At that time he made no suggestion of any relation between *Lepidodendron Spenceri* and the strobilus previously described.§

In the last Memoir of the series, however,‖ **WILLIAMSON** established the connection between the two. He says (p. 24): "Since the last of the above Memoirs (Part XVI.) was published, I have obtained specimens highly suggestive of the probability that the strobilus of Memoir IX., and the twigs named *L. Spenceri*, belonged to the same plant. This probability is now converted into a certainty by a specimen received from Mr. **LOMAX**, and now represented by fig. 41, Plate 7. It is an obliquely transverse section through a branch of *L. Spenceri* (C.N., 624E, × 10), but at its upper extremity A, it bears a portion of the strobilus of Memoir IX." There is no doubt that the conclusion at which **WILLIAMSON** thus arrived is correct; as we shall see, the so-called vegetative specimens of *Lepidodendron Spenceri* are nothing but the peduncles of cones. Unfortunately, the true vegetative organs, to which the fructifications belonged, are still unknown or unidentified.

In this Memoir, the author maintained his former opinion that the annular wing surrounding each spore, consists of its three sterile sister-cells. A very important addition to our knowledge is the description in Memoir XIX., of a fine longitudinal section of a strobilus; from this, **WILLIAMSON** rightly (though with some reserve) determined the mode of attachment of the sporangia to the sporophylls, a point which, as we shall see, is of the greatest importance in fixing the taxonomic position of the species.

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* "Organization," &c., Part X., 'Phil. Trans.,' 1880, p. 501. Read in 1879.

† *Loc. cit.* pp. 501–2, Plate 15, figs. 11 and 12.

‡ "Organization," &c., Part XVI., 'Phil. Trans.,' 1889.

§ *Loc. cit.*, p. 199, Plates 7 and 8, figs. 19–22.

‖ "Organization," &c., Part XIX., read 1892, published 1893.

In his 19th Memoir, WILLIAMSON points out that "the marked individuality of this rare type," "seems to justify its recognition as a distinct species." In his "General Index," however (Part II., p. 24, 1893), he goes further, and speaks of *Lepidodendron Spenceri*, as "a small and rare Lepidodendroid form, which presents so many peculiarities in its fructification, that it may possibly be necessary sometime, to make it the type of a new genus." In the "Index" the author gives an account of the variations met with in the structure of the central cylinder, and gives a fuller description of the cortex than before.

The only other account of the fossil known to me, is a short statement in Count SOLMS-LAUBACH'S 'Fossil Botany,' in which the structure of the spores is described, and the resemblance of the axis to that of *Lepidodendron Harcourtii* pointed out.*

The chief object of the present paper is to show, by means of a connected account of the whole structure, based on a comparative examination of the fairly numerous preparations now available, that WILLIAMSON'S suspicion of the generic distinctness of this fossil is fully justified, and that it thus represents a new type of Lycopodiaceous cone. A second species of the same genus will also be described.

A word as to nomenclature is necessary at the beginning, in order that the same name may be used throughout the paper.

As mentioned above, the specific name *Spenceri*, must be dropped, for that of *insignis* has the priority over it by ten years. As the fossil is a cone and not a vegetative stem, it would thus bear WILLIAMSON'S original name of *Lepidostrobus insignis*, were it not that its peculiarities, as will be shown below, demand generic separation. In order that the discoverer of the original specimens may still be commemorated, I have selected the generic name *Spencerites*, so that the species in question will be called *Spencerites insignis*, for which *Lepidostrobus insignis*, WILLIAMSON, 1879, and *Lepidodendron Spenceri*, WILLIAMSON, 1889, are synonyms. To this species all the specimens described and figured by WILLIAMSON in the 'Phil. Trans.' Memoirs belong. There is, however, a second species, a specimen of which is referred to in his "General Index,"† but not discriminated. For the new species the name *Spencerites majusculus* is proposed. Generic and specific diagnoses will be given at the close of the paper, after the structure has been described.

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* 'Fossil Botany,' 1887; English Edition, p. 239.

† Part 2, p. 24. This is the strobilus represented in the WILLIAMSON Collection by slides 624C and 624G.

I. SPENCERITES INSIGNIS (*Williamson*).

1. *The Axis and Bracts.*

It makes little difference whether the structure of the axis be studied in the peduncle or in the cone itself; the characters are practically the same, and present similar variations in both. The diameter of the axis ranges from 3·5 to 5 millims. As the epidermis can usually be traced as a continuous and unbroken layer, there can be no question that the specimens are complete externally, and that no part of the outer cortex has been lost (see Plate 13, fig. 6). The specimens of the peduncle often show the remains of foliar appendages, which are sometimes reduced to mere shreds, and are never preserved entire. Fig. 6 shows the best specimens of one of these appendages which I have found. It has a somewhat conical form, and evidently represents the stalk only of the organ; whatever there may have been of the nature of a lamina has perished, except for some torn shreds. These appendages closely resemble the stalks of the sporophylls in the actual cone (*cf.* Plate 14, fig. 11); on the other hand, they are totally unlike the bases of vegetative leaves in any of the Lycopods; they are best regarded as sterile bracts. Their bases by no means cover the whole exterior of the stem, as is the case in the vegetative regions of *Lepidodendron;* a considerable part of the surface is left free.

The material does not allow of the phyllotaxis being determined from the leaves themselves, for they are only preserved occasionally. From the position of the leaf-traces, however, some idea of the arrangement can be gained. On carefully following the leaf-traces in transverse section, through a complete circuit (not an easy undertaking, as their oblique course renders them excessively obscure), it appears that the arrangement is a very flat spiral.* The same conclusion follows, perhaps more clearly, from the examination of a tangential section through the cortex, as shown in Plate 13, fig. 7. The divergence between two adjacent leaves was about one-ninth or one-tenth of the circumference, as shown by the position of the leaf-traces in transverse sections, confirmed by a single case in which the bases of two adjacent leaves are preserved.† It is not improbable that at some places the spiral arrangement may have passed over into a verticillate one, with crowded alternating whorls.

Passing on to the anatomy of the axis, we find that the parts usually preserved are the following:—First, in the middle is the central strand of wood; around this is usually a narrow empty space, from which the soft tissues (probably phloem and pericycle) have, as a rule, perished. Then we come to a zone which may be called the inner cortex, in which the sections of the leaf-trace bundles may often be seen. Beyond this is another space, more or less empty in most of the sections, and of considerable width, representing the middle cortex, which in some cases is partly preserved.

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* C.N. 419B, for example, and other sections of the same group of peduncles.

† Slide No. 3 in my own collection.

To the outside of all is the zone of well-preserved, partly sclerotic, outer cortex, bounded externally by the epidermis, and bearing the foliar appendages, where these are preserved.* The chief variations in the structure of the central mass of wood have already been described by WILLIAMSON.† Sometimes the tracheæ occupy the whole area, extending quite to the centre; in other sections a few thin-walled cells occur in the middle of the strand; in others again, the central thin-walled tissue is more extensive, and appears to deserve the name of a medulla. These variations occur both in the sterile region, which I regard as peduncle, and in the strobilus itself.‡

Longitudinal sections show that the central thin-walled cells, when present, are prosenchymatous (Plate 13, fig. 8B, and WILLIAMSON, Mem. 16, Plate 7, fig. 22); they should perhaps be regarded in most cases rather as undifferentiated procambium than as constituting a true pith. This interpretation would agree well with WILLIAMSON'S observation that tracheæ with very delicate thickenings, apparently in course of development, occur in this central tissue,§ showing that the centripetal differentiation of the xylem was not yet complete near the centre, even when the organ was mature. Curiously enough, these central tracheæ are sometimes spirally thickened (fig. 8B), while those of the wood generally are scalariform, but they must not be confused with the narrow spiral tracheæ of the protoxylem, which here, as in Lycopods generally, lie at the extreme periphery of the wood (fig. 8A), and are usually somewhat disorganized.

In one of the strobili (C.N. 1922F *ter*, &c.), the central cells appear very thick-walled (see Plate 13, fig. 4). If this is really their natural condition, and not due to any process of infiltration, the medulla here differs from that of other specimens. There is no doubt from the other characters (spores, &c.), that this strobilus is of the same species with the rest.

Seen in transverse section, the protoxylem-angles (which correspond to the insertion of the leaf-trace bundles) are not very prominent—they are usually about 10 in number.

As a rule, the tissues immediately surrounding the wood have perished; in one case, however‖ (see Plate 13, fig. 5), the whole of the tissue between wood and inner cortex is preserved, though slightly crushed. This zone consists of small, thin-walled cells, no doubt representing the phloëm; slightly larger cells, which border on the coarser cortical tissue, may be regarded as pericyclic.

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* See Plate 13, fig. 4; also WILLIAMSON, 10th Mem., Plate 15, fig. 11, and 16th Mem., Plate 8, fig. 19.

† 'General Index,' Part 2, p. 25.

‡ Thus, of the four peduncles shown in C.N. 419B, and other sections of that block, some show solid wood, others a small medulla; the peduncle shown in C.N. 1922F *bis* has a considerable medulla. Similarly, the axis of the strobilus shown in Fig. 4 (C.N. 1922F *ter*), and that in C.N. 624, represented by WILLIAMSON (10th Mem., Plate 15, fig. 12), have a well-marked medulla, which appears to be entirely absent from the section C.N. 627, also of a strobilus.

§ "Organization," &c., 16th Mem., p. 199, Plate 7, fig. 22.

‖ Section No. 4 in my own Collection. Mr. SPENCER informs me that this was cut from the base of the same cone of which sections are figured by WILLIAMSON, in his 10th Mem., Plate 15, figs. 11 and 12 and 19th Mem., Plate 7, fig. 50.

The inner cortex, which is constantly preserved, consists of a few layers of fairly thick-walled somewhat elongated cells (see Plate 14, fig. 9). The broader middle cortex beyond has often disappeared, rather on account of its loose texture than because its cells were specially delicate. Sometimes the more coherent sheaths, surrounding the leaf-trace bundles, are alone preserved, while in other cases the whole of the middle cortical tissue has remained fairly perfect (see fig. 9). It consists of curiously interwoven, long, sometimes branched cells, with rather thick walls, resembling the form of trabecular tissue found by BOWER in the cortex of various Lycopods, recent and fossil.* These cells are connected, sometimes with the inner or outer cortex, sometimes with the sheaths of the leaf-trace bundles. Single cells of this layer may recall the curious internal hairs found in the cortex of the root of *Pilularia.*†

The outer cortex forms a fairly thick zone, nearly always well preserved, and consists in its external portion of more or less well-defined radial bands or masses of sclerenchyma, surrounded by rather more delicate tissue (see fig. 4), while its inner zone is more uniform, and without special groups of sclerenchyma. The sclerenchyma appears to constitute a network, the meshes of which are occupied by the more delicate tissues, through which the leaf-trace bundles pass out. The distinction between the two kinds of tissue is not always equally well marked, for sometimes the cell-walls are considerably thickened throughout the external cortex, but, on the whole, the "Dictyoxylon" structure of the cortex is characteristic, and serves, among other features, to distinguish *Spencerites insignis* from such forms as *Lepidodendron mundum,* WILL. The elements of the outer cortex are generally prosenchymatous. The small-celled epidermis is often very distinct (see fig. 6, *e*).

The leaf-trace bundles, as they start from the central cylinder, diverge but little from the vertical, gradually curving so as to assume a nearly horizontal direction before entering the bracts. The vertical distance traversed by each leaf-trace is small—about 0·8 millim.—and scarcely equal to the length of an internode (*cf.* Plate 13, fig. 7). Hence, the number of these strands met with in transverse section is small, usually about nine or ten, approximately equal to the number of appendages in one circuit of the spiral. Thus the leaf-trace bundles, owing to their small number and obliquity, by no means form so conspicuous a feature in the transverse section, as is usually the case in the axis of the *Lepidostrobi,* a distinction noted long ago by WILLIAMSON.‡

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* "On the Structure of the axis of *Lepidostrobus Brownii.*" 'Annals of Botany,' vol. 7, p. 341, Plate 17, 1893.

† RUSSOW, 'Vergl. Untersuchungen,' Plate 2, fig. 20.

‡ "Organization," Part X., 1880, p. 502.

Each bundle is surrounded by a strongly-developed sheath, which is especially evident where the lacunar middle cortex is traversed (Plate 14, fig. 9, *sh*). The structure of the bundles is best shown in tangential sections of the outer cortex (fig. 10). The phloem has almost wholly perished, but from the position of the parts it is most probable that the bundle was concentric; the smallest elements (protoxylem ?) lie toward the middle of the woody strand.

The bract-like appendages, or rather their stalks, which are alone preserved, consist of an outer envelope of thick-walled, elongated cells, within which is a more delicate tissue surrounding the vascular bundle.

The anatomical description just given applies equally to the sterile specimens, which I interpret as peduncles, and to the axis of the cone itself (compare Plate 13, fig. 4 with WILLIAMSON's figure in his 16th Memoir, Plate 8, fig. 19). So close is the agreement that the question arose whether the apparently barren specimens might not be simply withered fructifications, which had lost their sporangia, and partly lost their sporophylls, before fossilization. It is more probable, however, that the sterile portions really represent the peduncle of the cone, for in one specimen at any rate,* peduncle and cone were found in connection. The section (C.N. 624E) figured by WILLIAMSON in his 19th Memoir, Plate 7, figs. 41 and 42, was cut from the transitional region between the peduncle and the actual strobilus.

It also appears that the sporophylls of the cone itself were more crowded than the bracts of the sterile specimens. (Compare WILLIAMSON's figure in his 9th Memoir Plate 22, fig. 54, with fig. 7 in the present paper.)

2. *Sporophylls and Sporangia.*

The general organization of the cone has been fully described and illustrated by WILLIAMSON in his 9th and 19th Memoirs above cited. The longitudinal section represented in the latter Memoir, Plate 7, fig. 50, is extraordinarily perfect, and gives a better idea of the whole structure than any other preparation. In this case the arrangement of the sporophylls may not improbably have been in alternating verticils. The section passes directly through an orthostichy of sporophylls on either side of the axis. It is instructive to compare the tangential section, figured by WILLIAMSON (from another specimen) in his 9th Memoir, Plate 22, figs. 54, 55, which show very clearly the alternation of the sporophylls in the adjacent orthostichies. The short sporophylls and spherical sporangia give the cone a very different habit from that of a *Lepidostrobus*.

The form of the individual sporophyll is peltate; the stalk is horizontal, resembling that of the bracts already described; at the distal end it expands into a lamina, of looser tissue, projecting both upwards and downwards, so as to cover in the sporangia lying between. A single sporangium belongs to each sporophyll, as is evident from the comparison of sections in the three planes (see Plate 14, figs. 11 and 13, together with WILLIAMSON's figures above cited).

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* From which sections C.N. 624D, E, and F, and 1922F *bis*, in the WILLIAMSON Collection were cut.

The most important question relates to the point of insertion of the sporangia on the sporophylls. WILLIAMSON (19th Memoir, p. 25) determined this with perfect accuracy, though he expressed his opinion with some reserve. The sporangium is attached, by a narrow neck of tissue only, to the upper side of the sporophyll, near its distal end, where the lamina begins to expand. There is no attachment whatever to the horizontal pedicel of the supporting organ, and in this respect *Spencerites* differs entirely from any species of *Lepidostrobus.* The point of attachment is evident at several places in the radial section referred to. In Plate 14, fig. 11, which is taken from this preparation, the lower sporophyll is incomplete, but the insertion of the sporangium at *a* is unmistakable, though slightly obscured by a fragment of coal which overlies the connecting tissue. In the sporophyll next above, the connection with its sporangium is broken, but the point of attachment was no doubt at *a*. In fig. 12 from another preparation, a sporophyll is figured, which has been detached from its base, and is fortunately cut in the radial plane. The form of the lamina is well shown, and at *a* the remains of a sporangium, seated on its upper surface, near its junction with the pedicel, are evident. The points of sporangial insertion detected by WILLIAMSON, have been re-examined and his interpretation confirmed. A reference to WILLIAMSON's figure (19th Memoir, Plate 7, fig. 50, *e′* and *f″*) will show that the place of insertion is on the upward slope of the peltate lamina, here incompletely preserved. Our fig. 13 is from a transverse section, and shows very clearly that the sporangium is connected at its distal end with the sporophyll-lamina. The connecting neck of tissue was evidently wider in the tangential than in the radial plane. The vascular bundle approached very closely to the base of the sporangium and may have been connected with it by a short branch (figs. 11 and 12).

The structure of the sporangial wall was described and figured by WILLIAMSON in his first account of the fossil.* In its present state of preservation it is one cell only in thickness (except sometimes near the point of attachment); the cells of which it consists are prosenchymatous, their elongation lying in the plane of the sporangial surface, and not at right angles to it. They thus differ entirely from the palisade-like cells which usually constitute the wall of the sporangium in *Lepidostrobus.* The lateral septa of the cells of the sporangial wall are considerably thickened, while their top and bottom membranes are much more delicate.

3. *The Spores.*

The spores themselves have been very fully described by WILLIAMSON, whose interpretation of their structure, however, is, I believe, mistaken. Each spore, in its mature state, has approximately the form of an oblate spheroid, with a broad hollow wing running round its equator (see Plate 14, figs. 11 and 14A).* The maximum diameter of the spore itself is on the average 0·14 millim., while the whole diameter, including the wing, reaches 0·28 millim. The membrane of the spore is thick; that of the wing is excessively delicate. The cavity of the wing is widest at a short distance from its insertion on the spore, and narrows off towards its outer edge. WILLIAMSON interpreted the wing as consisting of the abortive sister-cells of the spore. For this view there is, I think, no evidence. The cavity of the wing always appears empty, whereas that of the spore itself constantly shows some remains of cell-contents. Also, the wing appears to be perfectly continuous all round the spore, and not to be in any way sub-divided into compartments or cells. The fusion of the three abortive sister-cells of a macrospore into such a continuous ring, is entirely without precedent, and can hardly be assumed in the absence of any positive evidence. The fact that the winged spores of *Spencerites* are often found still grouped in their original tetrads (see fig. 14B) is also opposed to the interpretation of each spore as itself representing a group of four sister-cells. On the latter assumption, we should have tetrads of tetrads, an arrangement for which there seems to be no analogy.

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* "Organization," Part IX., p. 341, Plate 22, fig. 38.

There is, I think, no doubt that the interpretation of the wing suggested by Count SOLMS-LAUBACH is the right one,† namely, that it "represents an organ analogous with the air-sacs of the pollen of the Pine." When seen in sectional view, the spore of *S. insignis* bears a considerable resemblance to the pollen grain of *Pinus* (see fig. 14), though, as the superficial aspect shows (see fig. 11; also, WILLIAMSON, 19th Mem., Plate 7, figs. 43 and 44), its real form is quite different, for in the fossil the air-sac forms a continuous rim all round the spore, a fact not recognised by Count SOLMS-LAUBACH. There is little doubt, however, that the wing agrees with the air-sacs of *Pinus* pollen in being formed by a dilation of the cuticle, and probably its function was the same.

The four spores of a tetrad are arranged tetrahedrally, as is shown with great clearness in some of the sporangia (see Plate 14, fig. 14B, and compare with WILLIAMSON, 9th Mem., Plate 22, fig. 57). At this stage, the tetrahedral form of the individual spores is still evident; when they become free their shape grows more spheroidal. The lines of junction of the three sister-cells are indicated on the spore by three sharp ridges, meeting each other at an angle of 120° (see WILLIAMSON, 19th Mem., Plate 9, fig. 49, and fig. 14A in the present paper).

The wings lie in the planes of the four free surfaces of the tetrahedral group (see fig. 14B). Hence the wing of each spore, as seen in surface view, has a somewhat triangular outline (see fig. 11).

The cell-contents of the spore are often represented merely by a dark carbonaceous mass in the middle of the cell. In other cases, however, the central body shows a very definite structure, forming a regular reticulum, suggestive of a cellular tissue (fig. 14A, *cb.*). In other cases again, a number of small spherical spore-like bodies are contained within the large spore, a condition which has been repeatedly figured by WILLIAMSON.[*] These minute spore-like bodies have an average diameter of about 0·02 millim. They have a very distinct outline, and evidently possess a membrane of their own, which in some cases has split. Similar sporules, as we may provisionally call them, also occasionally occur free in the cavity of the sporangia; in one case where this was noticed, two large spores in their neighbourhood had manifestly burst, and there is little doubt that it was from them that the free sporules had been derived. In some cases appearances are met with within the larger spores, which indicate that the sporules may be developed from the central reticulum. The latter body has been interpreted as a prothallium, a very tempting idea, and probable enough if we consider the analogous case observed by M. RENAULT in the pollen grains of *Cordaites.* It is impossible to arrive at a certain conclusion, but the impression left on one's mind, after the examination of a great number of spores, is rather that the reticulum is the expression of some pathological or *post-mortem* change in the cell-contents. The definite cellular appearance seems to be only a particular case of a variable and inconstant frothy coagulation. How, then, are we to interpret the free sporules which occasionally appear, and which seem to have been sometimes set free by the bursting of the spores within which they were formed? Various possible views were discussed by WILLIAMSON, without his reaching any decisive conclusion.[†] The sporules are of comparatively rare occurrence, and I do not myself believe that they form part of the normal structure of the spores. That the large winged bodies really are the spores (whether microspores or macrospores) can no longer be doubted, and the production of spores within spores would be a phenomenon without analogy among Vascular Cryptogams.[‡] I therefore incline to regard these sporules as foreign bodies, possibly the product of some low organism, parasitic or saprophytic, within the spore. Fungi living and fructifying within pollen grains and spores are well known at the present day.[§]

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* Also WILLIAMSON, "Organization," Part IX., Plate 22, figs. 46, &c., and Part XIX., Plate 7, figs. 43 and 44.

† 'Fossil Botany,' English edition, p. 239.

Another possibility which has been suggested to me is that the "sporules" may merely represent altered vesicular aggregations of the protoplasm of the spores. Such bodies have often been observed in the cells of recent plants, when rich in tannin, and may present a deceptive resemblance to Fungal or Myxomycetous spores. Structures, probably of the same nature, have also been detected in fossil vegetable tissues.* The great definiteness of the membrane of the "sporules," which has sometimes split, with a perfectly sharp fissure, suggests however the cuticularized cell-wall of an actual spore, rather than a mere precipitation-membrane. In any case, it will be safer, in the present state of our knowledge, to leave the "sporules" out of consideration, in discussing the morphology of the spores of *Spencerites.*

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[*] "Organization," Part IX, Plate 22, figs. 42–44; Part XIX., Plate 9, fig. 48.

[†] "Organization," Part IX., p. 343.

[‡] Spermatozoid mother-cells might be thought of in this connection, but such cells, as known to us among recent plants, are far too delicate to be preserved in so definite a form.

[§] E.g., *Rhizophidium pollinis, Olpidium pendulum, Lagenidium pygmaeum.* See ZOPF, "Die Pilze," in SCHENK'S 'Handbuch der Botanik,' vol. 4, pp. 296, 297, and 556.

We have at present, no means of determining whether *Spencerites insignis* was homosporous, or if heterosporous, whether the winged spores represent microspores or macrospores. In dimensions they are intermediate between the two, if we compare them with the spores of other Lycopods. The maximum diameter of the spore of *Spencerites insignis* (not counting the wing) is pretty constantly about 0·14 millim. The microspores of *Lepidostrobi* are very much smaller, usually about 0·02 to 0·03 millim., though those of *L. Brownii* Schp. reach a diameter of about 0·05 millim. On the other hand, the macrospores of the Carboniferous Lycopodiaceæ were usually of very large size. Of the numerous macrospores described by Mr. KIDSTON† (among which those of *Sigillariostrobus* as well as *Lepidostrobus* are probably included) the great majority are from 1 to 2 millims. in diameter; the smallest exceeds 0·5 millim. Macrospores belonging to *Lepidostrobi* from Oldham and from Burntisland, which I have measured, were about 0·8 millim. in diameter. The macrospores of *Sigillariostrobus* were very large, varying from 1·5 millim. to 2 millims. in different species.‡ The macrospores of recent heterosporous Lycopods (*Selaginella* and *Isoëtes*) range from about 0·2 to 0·5 millim.

On the whole then, it appears that the spores of *Spencerites insignis* are decidedly large for microspores, and decidedly small for macrospores. The comparatively small numbers in which they occur in each sporangium (see fig. 11) would suggest the latter rather than the former, but no conclusion can be drawn. So far as I can ascertain, only four distinct specimens of the actual cone are known. In these, all the sections (which in two of the specimens include the base of the cone) show spores of one kind only. A few minute spore-like bodies have occasionally been detected, but, as mentioned above, they appear to have escaped from the interior of large spores, and to be foreign or pathological products, and certainly not microspores.

4. *Abortive Sporangia.*

In one of the sections of the original specimen of the cone,§ some of the sporangia shown have a very different appearance from the ordinary ones, and offer, at first sight, a startling resemblance to seeds. One of these sporangia is shown in detail in Plate 15, fig. 15. In this case the section evidently passes medianly through the sporangium, so WILLIAMSON'S interpretation "sporangial wall," which would imply that it is cut tangentially, will not hold good here. The anomalous sporangia, which are much smaller than the normal organs, are evidently attached, as usual, at their distal ends, but the sporophylls in this part are crowded and apparently somewhat displaced. WILLIAMSON supposed, no doubt with good reason, that this section was cut near one end of the strobilus.*

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* SEWARD, "On *Cycadeoidea gigantea*;" 'Quarterly Journal of the Geological Society,' Feb., 1897, vol. 53, p. 26.

† J. BENNIE and R. KIDSTON, "On the Occurrence of Spores in the Carboniferous Formation of Scotland." 'Proc. Roy. Phys. Soc.,' Edinburgh, vol. 9, p. 82, 1886.

‡ ZEILLER, "Cones de Fructification de *Sigillaria*;" 'Ann. des Sci. Nat. (Bot.),' Ser. 6, vol. 19, 1885.

§ See WILLIAMSON, "Organization," Part IX., Pl. 22, fig. 53*e*, C.N. 626.

The wall of the anomalous sporangia appears to have been several cells in thickness. The cavity is partly filled by a carbonized mass, showing some traces of a cellular structure, and seated on a pad of tissue at the end where the sporangium is itself attached to its sporophyll. From the black mass delicate fibrils radiate, connecting it in places with the sporangial wall, from which it appears to have contracted away, before fossilization.

None of the other sections, either of the same or of different specimens, show these anomalous sporangia, which, in all probability, are simply abortive organs, the development of which had been arrested at a rather early stage. If so, they afford evidence that the inner layers of the wall were absorbed as the sporangium became ripe.

The consideration of the affinities of *Spencerites insignis* will be postponed until the next species has been described.

II. SPENCERITES MAJUSCULUS, *sp. nov.*

1. *General Characters.*

This form was not described or distinguished from the previous species by WILLIAMSON, though two sections of it are cited in his "General Index,"† under the head of "*Lepidodendron Spenceri.*" So far as I know, only one specimen of the new species has ever been found. This was discovered by Mr. J. SPENCER, who prepared a number of sections from it. Only two of these (both transverse) are in the WILLIAMSON collection. I have examined numerous other preparations, including four longitudinal sections, two of which, one radial and the other tangential, are figured in the present paper, in addition to a transverse section (Plates 12 and 13, figs. 1, 2, and 3). The comparison of all the sections examined has completely cleared up the important points in the structure of the strobilus, and has shown that it is nearly allied to, though quite distinct from, the former species.

The specimen consists of the strobilus only; all the sections show the sporophylls borne upon the axis. The diameter of the whole cone, including the sporophylls is about 15 millims., while that of the axis is quite 9 millims., much larger than that of *S. insignis*, which does not exceed 5 millims. The short sporophylls and thick axis give a characteristic habit to the fruit. The diameter of the central cylinder is about 1·7 millims., quite double that in the former species (see Plate 12, fig. 1, and Plate 15, fig. 17). The state of preservation is similar to that of most specimens of *S. insignis;* the wood is perfectly preserved; only slight remains of the phloem are present; the inner zone of cortex immediately surrounding the central cylinder is in good preservation; beyond this is a wide empty space, from which the middle cortical tissue has entirely disappeared, except that in some cases the leaf-trace bundles, enclosed in their sheaths, are seen crossing the gap (fig. 17). Lastly, the dense layer of outer cortex is perfect and bounded by a definite epidermis.

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* *Loc. cit.*, Part IX., p. 341.

† Part II., p. 25. The sections are 624c and 624d.

The arrangement of the sporophylls cannot be determined with certainty from the transverse sections, but the tangential section (represented in Plate 13, fig. 3) leaves little doubt that, in this part of the cone, at any rate, they were placed in alternating verticils. Judging from the position of the sporophyll-bases, as shown in transverse section, the number of members in each verticil must have been fourteen or fifteen. The form of the sporophylls and their relation to the sporangia will be considered below.

2. *The Axis.*

Taking the structure more in detail, and beginning with the stele of the axis, we find that the wood extends to the centre, without any indication of a pith or of conjunctive parenchyma (Plate 12, fig. 2, and Plate 15, fig. 17). At the periphery of the wood are a large number (about thirty) of prominent groups of very small tracheæ, which the radial section shows to be spiral. Elsewhere, the elements of the wood are of the usual scalariform type. The large number of protoxylem-groups is a marked difference from *S. insignis*, where their number is usually about ten, and has not been found to exceed fourteen. Their number in the present species appears to correspond to that of the orthostichies of sporophylls, and is therefore double the number of the members in each verticil. There are some slight remnants of the soft tissue (no doubt phloem), immediately surrounding the xylem (fig. 17, *ph.*).

The inner cortex consists of several layers of rather delicate, elongated cells (figs. 1, 2, and 17). The broad zone of middle cortex has entirely disappeared, leaving an empty gap, crossed in some places by the leaf-trace strands (fig. 17). The outer cortex consists of almost uniform sclerotic tissue, the elements of which are prosenchymatous (figs. 1 and 2). There is no differentiation into radial bands of diverse structure, and this uniformity of the outer cortex forms another distinction from *S. insignis*, in which the corresponding zone has the "Dictyoxylon" character.

The leaf-trace bundles are met with at all points of their outward course, and are best seen in transverse sections through the inner cortex (fig. 17). Both in their direction and structure they agree closely with those of *S. insignis*, but, they appear in greater numbers in transverse section.

3. *The Sporophylls and Sporangia.*

The form of the sporophylls is a complex and peculiar one. Each sporophyll consists of a petiole and a lamina. The former is inserted, with a somewhat broad base, on the axis, and tapers towards the distal end (compare Plate 12, figs. 1 and 2; Plate 13, fig. 3, and Plate 15, fig. 16). The sectional form of the petiole is that of an ellipse, with its main axis horizontal (fig. 3). In general appearance this part of the sporophyll is similar to that of *S. insignis*. As in that plant the outer tissue of the petiole is prosenchymatous and thick-walled; within this, is a more delicate strand of parenchyma, enclosing the vascular bundle.

The laminæ are expremely conspicuous objects in all the preparations (see Plate 12, figs. 1 and 2; Plate 13, fig. 3), though in the transverse sections their connection with the rest of the specimen is not usually evident (fig. 1). The point of connection between petiole and lamina was evidently a weak place in the tissue, and has generally broken down, but in several cases, as in the sporophyll figured, in radial section, in Plate 15, fig. 16, the continuity is perfect, though there is a bend or kink at the weak spot.

The lamina widens and broadens out suddenly, in every direction, from its point of attachment to the petiole. Its greatest dimension is in the tangential direction, in which its width is about 3 millims. (figs. 1 and 3). In the radial plane the lamina reaches a length of about 2·5 millims. (figs. 2 and 16). The extreme vertical height or thickness is about 2 millims., as best shown in the tangential section (fig. 3). This section, which passes rather obliquely through the laminæ towards the left-hand side, gives an excellent idea of the way they were packed together in alternating rows, each lamina thus acquiring a somewhat diamond-shaped outline. At its outer margin the lamina thins out into a narrow horizontal ridge, shown in figs. 2, 3, and 16.

The laminæ must have had a fleshy character during life; they consist almost wholly of a very large-celled parenchyma, bounded externally by an epidermis of smaller cells, with thickened external walls (fig. 16). The small vascular bundle runs near the upper surface. The thick fleshy laminæ form a most characteristic feature of the species.

Fragments of the sporangia, with their contained spores, occur everywhere in the space between the laminæ and the axis (figs. 1, 2, and 3). In their shattered condition, the form of the sporangia cannot be determined with any exactness, but judging from the better preserved specimens, it would seem to have been approximately spherical, as in *S. insignis* (Plate 15, fig. 16). The important question of the insertion of the sporangia on the sporophylls could only be determined by the comparison of a number of instances. The sporophyll shown in radial section, in fig. 16, gives a good idea of the relative positions. The sporangium is certainly free from the petiole. It appears to have been attached on the upper surface exactly at the point (*a*) where the petiole passes over into the lamina. From this case alone, one could not be certain that the sporangium might not also have been adherent to the upper face of the lamina itself, but other sporophylls show clearly that the two organs were free from each other in this region, and that the only attachment was at the point indicated. In particular, the tangential section, shown in Plate 13, fig. 3, is conclusive as to the absence of any adhesion between lamina and sporangium. At *a* the plane of section passes through the junction of the lamina and petiole of one of the sporophylls, and here the remains of a sporangium attached to the upper surface at this point are clearly seen. It appears then that the place of insertion of the sporangium in this species is essentially the same as in *S. insignis*, though relatively nearer the axis, owing to the great development of the laminar portion of the sporophyll in *S. majusculus*.

The membrane of the sporangium, in its present condition, consists of a single layer of prosenchymatous cells, and is much like that of *S. insignis* (see Plate 15, figs. 18 and 19). Seen in transverse section, the cells appear triangular, their thick lateral walls forming a regular zigzag, more definite here than in *S. insignis*. The inner and outer cell-walls are delicate, the outer usually the better preserved of the two (fig. 19A).

4. *The Spores.*

The spores, sometimes found within the sporangium, and sometimes scattered about outside, are very characteristic, and afford, perhaps, the best diagnostic character of the species. The spores of *S. majusculus* are not tetrahedral like those of *S. insignis*, but have the form of quadrants of a sphere (see Plate 15, fig. 19B–E). They are winged, but in quite a different way from those of the former species, for in *S. majusculus* each spore has three wings running along the three angles of the quadrant (fig. 19B and E). The wings themselves are thin, and not obviously hollow like those of *S. insignis*. The dimensions are smaller, the extreme length of the spore without wings varying from 0·09 to 0·12 millim., and inclusive of the wings reaching 0·15 millim. Thus the wings are narrower, and the dimensions of the winged spore, as a whole, little more than half those of *S. insignis*. Remains of the contracted cell-contents are often found, and occasionally distinct, cell-like bodies, comparable, perhaps, to the similar structures in the former species, occur within the spores. In one preparation (C.N., 624C) a few minute spore-like bodies were found free, but their connection with the specimen is altogether doubtful.

The spores are occasionally found grouped together, as if in their original tetrads (figs. 19D and E). They are arranged, as might be expected from their form, like the quadrants of a sphere, and not in tetrahedrons. The spores are, on the whole, less perfectly preserved than in *S. insignis*, but the difference between those of the two species is evident at the first glance. (Compare Plate 14, figs. 11 and 14 with Plate 15, fig. 19.)

CONCLUSIONS.

There are two questions to be considered in conclusion: the relation between the two forms which have been described, and the relation of both together to other plants. The smaller question will be taken first.

No one who has compared the specimens which I have referred to *Spencerites majusculus* and *S. insignis*, or the drawings of their structure accompanying the present paper, is likely to doubt that the two forms are specifically quite distinct. The great difference in absolute dimensions (the axis of *S. majusculus* being about twice as thick as that of *S. insignis*), though striking enough, would go for little if it stood alone. It is accompanied, however, by a considerable difference in the *relative* dimensions of axis and sporophylls, and by marked structural distinctions, in the outline of the wood, the arrangement of the leaf-trace bundles, and the details of the outer cortex. The sporophylls are not only much larger in *S. majusculus* than in *S. insignis*, while relatively shorter in the former as compared with the size of the axis, but have a somewhat different form, though the superior preservation of these organs in the former renders exact comparison difficult. The great tangential width of the lamina is characteristic of *S. majusculus*, while the peltate form, as seen in radial section, is more marked in *S. insignis*. The sporangia are similar in both, but the spores are quite different, those of *S. insignis* being decidedly the larger, of tetrahedral or spheroidal form, with a broad equatorial wing, while those of *S. majusculus* are smaller, with the form of quadrants of a sphere, each spore having three narrow wings running along its angles. The difference in the dimensions of the spores is not sufficient to justify us in regarding them as microspores and macrospores of the same species, nor would such a suggestion be consistent with the other marked distinctions between the strobili.

On the other hand, the two species, distinct as they are, have much in common. The general anatomy is similar; in this respect the two forms resemble each other more closely than they resemble any other known strobilus. The sporophylls, with their broad laminæ, sharply marked off from the almost cylindrical petiole, are characteristic of both forms jointly. The insertion of the sporangium, by a narrow attachment, to the upper surface of the sporophyll, where it begins to expand into the lamina, is as I have shown, essentially the same in both. The spores also have something in common, at least in the fact that they are winged, while the form and structure of the sporangium are alike in both.

These various points of agreement and difference find, I believe, their best expression, if we regard the two forms as two species of the same genus.

We now come to the more important question of the relation of these forms to other plants, and especially to other members of the Palæozoic Flora.

That the strobili are Lycopodiaceous can scarcely be questioned, for this conclusion follows at once from the position of the sporangia, seated singly on the upper surface of each sporophyll, and from the whole anatomical structure.

It is natural to place any Palæozoic Lycopodiaceous cone, in the first instance, in the genus *Lepidostrobus*, and this is the position hitherto assigned to *Spencerites insignis*, though WILLIAMSON, as already mentioned, thought it might ultimately be necessary to make it the type of a new genus.* I think the results of the renewed examination of this fossil, and the discovery of a second allied species, indicate that the time has come when WILLIAMSON'S suggestion should be carried into effect.

We may take the generic character of *Lepidostrobus*, given by M. ZEILLER, as fairly representing the modern conception of the genus. In the following literal translation the italics are M. ZEILLER'S own: "*Cones of fructification* cylindrical, oblong, or ovoid; composed of a woody axis bearing sporangiferous bracts arranged in a spiral, and somewhat crowded. *Bracts formed of a narrow pedicel*, usually normal to the axis, *and of a uni-nervate limb, lanceolate or linear-lanceolate in outline*, generally erect, and often even applied to the surface of the cone. Sporangia ovoid, solitary, fixed upon the superior face of the pedicel of the bracts."† Of these characters the spiral arrangement of the sporophylls is, perhaps, the least constant, for M. ZEILLER himself points out in the same work that in his *Lepidostrobus Olryi* the phyllotaxis is verticillate. I therefore attach no importance to the fact that in *Spencerites* the arrangement appears to have been variable in this respect.

In several points, however, the strobili described above diverge from the character of *Lepidostrobus*. The form of the limb or lamina is totally unlike, and its preservation, especially in *S. majusculus*, is sometimes sufficiently perfect for us to be sure that the difference is a real one. The sporangia are not ovoid, but approximately spherical, and, which is the chief point, they are not fixed upon the superior surface of the pedicel, but are altogether free from this part of the sporophyll, and only attached, by a narrow base, to the lamina where it begins to expand. It is instructive to compare such a species of *Lepidostrobus* as *L. Olryi*, ZEILL. with our strobili. In dimensions and general form *L. Olryi* appears to be not unlike our *Spencerites insignis*, but, in the former, the attachment of the elongated sporangium to the whole upper surface of the pedicel is evident from M. ZEILLER'S detailed figure, and at once distinguishes this species as a true *Lepidostrobus*.‡

The attachment of the sporangium, either by the whole length of its lower surface, or by a considerable part of it, to the upper side of the pedicel, appears to be constant in all species of *Lepidostrobus* where the preservation is sufficiently good for such points to be determined, and must, in my opinion be regarded as an essential character of the genus.§ It is chiefly on this ground, then, that I base the generic separation of *Spencerites* from *Lepidostrobus*, but the character derived from the insertion of the sporangia is supported by several others, namely the form of the sporophylls and sporangia, the structure of the sporangial wall, and of the spores, the arrangement of the leaf-traces, and the whole habit of the strobilus.

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* 'General Index,' Part II., p. 24, 1893.

† ZEILLER, "Bassin Houiller de Valenciennes." 'Flore Fossile,' 1888, p. 496.

‡ ZEILLER, *loc. cit.*, Atlas, Plate 77, figs. 1 and 1A.

§ Any of the published figures of well-preserved *Lepidostrobi* will serve to illustrate this character

The resemblance of *Spencerites insignis* to a cone described by M. ZEILLER under the name of *Sigillariostrobus Crepini** is rather striking, and for some time led me to suppose that both our species might belong to the genus *Sigillariostrobus*, in which case they would have been of special interest as the first known fructifications of *Sigillaria* with their structure preserved.† M. ZEILLER most kindly sent me the type specimen of *S. Crepini* for examination, so I was able to compare it directly with the preparations of our strobili. M. ZEILLER'S fossil is preserved in the form of impressions, of which there are two on the same fragment of rock. As M. ZEILLER pointed out in a letter to me, the dark colour of the matrix somewhat obscures the details of the fossil, but I was able to satisfy myself as to all the important points shown in the author's figures. *Sigillariostrobus Crepini* agrees with *Spencerites insignis* in the dimensions of the axis, the arrangement of the sporophylls, and to some extent in their form. So far as can be ascertained, the two plants also agree in the position of the sporangia, which in *Sigillariostrobus Crepini* appear to be free from the pedicel and attached at the distal end to the spoon-shaped lamina of the sporophyll. The point is, of course, comparatively obscure in the French fossil, owing to its mode of preservation, but I believe M. ZEILLER'S interpretation to be the correct one.

Up to this time nothing whatever was known of the sporangia (as distinguished from the spores) of *Sigillariostrobus*, with the solitary exception of *S. Crepini*, so it was permissible to suppose that their insertion at the distal end of the sporophyll might be characteristic of the genus.

Since then, however, owing to the kindness of my friend, Mr. R. KIDSTON, F.G.S., I have had the opportunity of examining a fine specimen of his *Sigillariostrobus ciliatus*, in which the sporangia containing the macrospores are well preserved. Mr. KIDSTON is about to publish a full account of the fossil in the 'Transactions of the Royal Society of Edinburgh,'‡ so I will only say that the examination of the specimen in question appears to leave no doubt that in this *Sigillariostrobus* the

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The diagram by WILLIAMSON, "Organization," Part XIX., Plate 6, fig. 62, is quite true to nature for *Lepidostrobus Oldhamius*, and contrasts sharply with *Spencerites insignis*, as shown in Plate 7, fig. 50 of the same memoir. HOOKER'S figure, from *L. ornatus* ('Mem. Geol. Survey of Great Britain,' vol. 2, Part II., Plate 8, fig. 11, 1848), reproduced in various text-books, *e.g.*, SOLMS-LAUBACH, 'Fossil Bot.,' fig. 25C, may illustrate another type, which would approach rather nearer to *Spencerites*, though still quite distinct.

* ZEILLER, "Bassin Houiller de Valenciennes." 'Flore Fossile,' Plate 77, fig. 3.

† See 'British Association Report,' 1896, p. 1024.

‡ This has now appeared: "On the Fossil Flora of the Yorkshire Coal-field; Second Paper." *Loc. cit.*, vol. 39, Part I., No. 5, 1897.—Jan. 26, 1898.

sporangium is attached along the whole of its lower surface to the horizontal pedicel of the sporophyll, and that it is partly roofed in above by a kind of indusium, arising from the upturned lamina, as in Isoëtes. In these points (to which Mr. KIDSTON first called my attention) *Sigillariostrobus ciliatus* differs entirely from *Spencerites*, and apparently from *Sigillariostrobus Crepini* also.

In the face of these facts it is impossible to unite *Spencerites* with *Sigillariostrobus*, any more than with *Lepidostrobus;* our two species are best regarded as the representatives of a distinct Lycopodiaceous genus.

This conclusion leaves us in doubt as to the true nature of M. ZEILLER's *Sigillariostrobus Crepini.* As that author points out, it seems to be quite distinct from *Lepidostrobus*, and to bear a considerable likeness to some undoubted *Sigillariostrobi*, especially *S. Goldenbergi*, ZEILLER.*

Possibly *Sigillariostrobus*, as at present constituted, may have to be broken up into two or more genera, in which case it may be that *S. Crepini* and our *Spencerites* may still be brought together. Until, however, we are acquainted with the internal structure of the Sigillarian fructifications, no definitive re-arrangement can be carried out.

In the insertion of the sporangium, by a narrow base, on the distal portion of the sporophyll, *Spencerites* differs from all other known Lycopods. It is at the opposite extreme from *Selaginella*, where the sporangia are axillary. There is a certain analogy with the insertion of the synangium in Psilotaceæ, especially *Tmesipteris*, but this comparison is of doubtful value, so long as the homologies of the Psilotaceous synangium remain uncertain.† If Professor BOWER is right in believing that the synangium represents a single, elaborated sporangium, then the comparison with *Spencerites* may hold good. But if, as GOEBEL‡ supposed, the synangium corresponds to a fertile branch, or if, as I have ventured to suggest in a previous paper,§ it represents the sporangiferous pedicel in Sphenophylleæ, then the structure is no longer comparable with that of our fossil. However this may be, the Psilotaceæ appear to be too remote from the strobiloid Lycopods to throw much light on a fructification like that of *Spencerites*.

In the fact that the insertion of the sporangium is broader in the tangential than in the radial direction, the new genus differs conspicuously from *Lepidostrobus*, and resembles some living species of *Lycopodium*, such as *L. clavatum* and *L. Selago.*‖

The distal insertion of the sporangium—reminding us of *Cheirostrobus* and the Sphenophylleæ, otherwise so remote—may perhaps be an indication that *Spencerites* represents a somewhat more archaic type of Lycopodiaceous strobilus than that of *Lepidostrobus.*

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* *Loc. cit.*, Plate 89, fig. 1.

† See BOWER, "Studies in the Morphology of Spore-producing Members," Part I., 'Phil. Trans.,' B, vol. 185, 1894, p. 539, where the various interpretations are stated.

‡ 'Bot. Zeitung,' 1881.

§ "On *Cheirostrobus*," &c., 'Phil. Trans.,' B, vol. 189, p. 1, 1897.

‖ BOWER, *loc. cit.*, Plate 47, fig. 92.

DIAGNOSIS.

Spencerites, gen. nov.

Cone consisting of a cylindrical axis, bearing numerous simple sporophylls, arranged spirally, or in crowded alternating verticils.

Sporophylls short, formed of a sub-cylindrical pedicel expanding into a large peltate lamina.

Sporangia, solitary on each sporophyll, inserted, by a narrow base, on the upper surface of the lamina, but free from the pedicel.

Sporangial wall, formed of a single layer of prosenchymatous cells.

Spores winged.

1. *Spencerites insignis* (WILL.).

   Lepidostrobus, sp., WILLIAMSON, "Organization of the Fossil Plants of the Coal-Measures," Part IX., 'Phil. Trans.,' 1878, p. 340, figs. 39 to 47 and 52 to 57. *Lepidostrobus insignis*, WILL., *loc. cit.*, Part X., 'Phil. Trans.,' 1880, p. 502, figs. 11 and 12. *Lepidodendron Spenceri*, WILL., *loc. cit.*, Part XVI., 'Phil. Trans.,' 1889, p. 199, figs. 19 to 22. *Loc. cit.*, Part XIX., 'Phil. Trans.,' 1893, p. 24, figs. 41 to 50.

   Cone pedunculate. Peduncle bractigerous.

   Whole cone, 8 to 10 millims. in diameter.

   Axis, 3·5 to 5 millims. in diameter.

   Sporophylls, 2 to 2·5 millims. long; lamina distinctly peltate, vertically elongated.

   Sporangia approximately spherical.

   Spores tetrahedral, becoming spheroidal when free, with a hollow equatorial wing.

   Maximum diameter of spore without wing, about 0·14 millim.; with wing, about 0·28 millim.

   Wood of axis, 10-arch to 14-arch, without prominent angles; with or without pith. Outer cortex containing distinct bands of sclerenchyma.

   Locality, near Halifax and Huddersfield.

   Horizon, Lower Coal-Measures.

2. *Spencerites majusculus*, sp. nov.

   Whole cone, about 15 millims. in diameter.

   Axis, about 9 millims. in diameter.

Sporophylls, about 3 millims. long; lamina obscurely peltate, as seen in radial section, but greatly expanded tangentially, attaining a breadth of 3 millims.

Sporangia approximately spherical.

Spores, having the form of quadrants of a sphere, with three narrow wings.

Maximum diameter of spore without wings, on the average about 0·11 millim.; with wings, about 0·15 millim.

Wood of axis, with about thirty somewhat prominent angles; without pith.

Outer cortex uniformly sclerotic.

Locality, near Halifax.

Horizon, Lower Coal-Measures.

It must be remembered that *S. majusculus* is described from a single specimen, so it is to be expected that the specific character will require modification in the future. The specimens of *S. insignis* are more numerous, but so far as the actual strobilus is concerned, I am only acquainted with four distinct examples.

In addition to the slides in the WILLIAMSON Collection and in my own, I have had the use of two sections lent by Mr. SPENCER, and of preparations from the HICK, WILD, and CASH Collections in the Manchester Museum. For the loan of the latter I am indebted to Professor F. E. WEISS, of the Owens College.

Of the illustrations to this paper, six, namely, figs. 1, 2, 3, 4, 5, and 12, were drawn for me by Mr. G. T. GWILLIAM, and the remainder by Mr. W. C. WORSDELL.

EXPLANATION OF PLATES, 12–15.

PLATE 12.

Spencerites majusculus.

Fig. 1. Transverse section of strobilus. *x.*, wood of axis; *i.c.*, inner cortex; the middle cortex has perished, leaving a space into which Stigmarian rootlets have penetrated; *o.c.*, outer cortex, in which the leaf-trace bundles can be seen at several places; *sm.*, remains of sporangia, containing spores; *sph.*, bases of sporophylls; *sph'.*, laminæ of sporophylls. × 10. S., 7* (from Mr. J. SPENCER) (see pp. 95 and 96).

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* Slides in my own Collection are indicated by the letter *S* before the number; those in the WILLIAMSON Collection are marked C.N. (Cabinet number) as heretofore. Slides from other Collections are specially referred to.

Fig. 2. Radial section of strobilus. *x.*, wood of axis; *i.c.*, inner cortex; the middle cortex only shows fragments of leaf-trace bundles, and an intruding Stigmarian rootlet; *o.c.*, outer cortex; *sm.*, sporangia, containing spores; *sph.*, bases of sporophylls; *sph'.*, their laminæ. × 9. From a slide in Mr. J. SPENCER's Collection (see pp. 95 and 96).

PLATE 13.

Fig. 3, *Spencerites majusculus;* figs. 4 to 8B, *S. insignis.*

Fig. 3. *S. majusculus.* Tangential section of strobilus. The section is slightly oblique, passing through the cortex of the axis above, and through the sporophyll-pedicels, below. On either side the laminæ are shown, best preserved on the left hand. *ax.*, axis with bases of sporophylls; *sph.*, pedicels of sporophylls; *sph'.*, their laminæ. Note the regular alternate verticils. *sm.*, remains of sporangia, containing spores; *a.*, insertion of a sporangium. × 6. From a slide in Mr. J. SPENCER's Collection (see p. 96). For other figures of *S. majusculus* see Plate 15.

Fig. 4. *S. insignis.* Transverse section of a strobilus. *x.*, wood of axis, enclosing a thick-walled pith; *i.c.*, inner cortex; middle cortex penetrated by Stigmarian rootlets; *o.c.*, outer cortex, with "Dictyoxylon" structure; the leaf-trace bundles are seen both here and in the inner cortex: *sph.*, sporophylls, imperfectly preserved; *sm.*, sporangia, containing the winged spores; *s.r.*, Stigmarian rootlet. × 10. From a slide by Mr. J. LOMAX in the WILD Collection (No. 159), Manchester Museum. Other sections of the same cone are in the WILLIAMSON* and HICK Collections, and in my own (see pp. 86–90).

Fig. 5. Transverse section (from the base of a strobilus) of the stele and inner cortex. The large central mass, *x.*, is the wood; *p.h.*, phloem-zone, somewhat crushed; *i.c.*, inner cortex. × 50. S., 4 (from Mr. J. SPENCER). Other sections of the same cone are in the WILLIAMSON† and CASH Collections (see p. 87).

Fig. 6. Part of a transverse section from a peduncle, to show bract. *e.*, epidermis; *c.*, outer cortex, the external layers of which are very thick-walled; *l.t.*, leaf-trace bundle, passing out to bract.; *b.r.*, bract. C.N., 419G (from Mr. J. SPENCER). × 45 (see p. 86).

Fig. 7. Tangential section through the cortex of a peduncle to show the arrangement of the leaf-trace bundles, which appear to form a flat spiral with a

* C.N. 1922F, *ter*.

† C.N. 624, 624A and B 625.

small divergence; slightly diagrammatic; *l.t.*, leaf-trace bundles. In many of them the group of tracheæ can be seen, and also the bundle-sheath; *b.r.*, base of a bract. × 18. C.N., 419D (from Mr. J. SPENCER) (see p. 86).

Fig. 8A. Tracheæ from the extreme outer edge of the wood, seen in radial section. *px.*, *px.*, small spiral tracheæ of the protoxylem, somewhat disorganized. The larger element to the right (*i.e.*, towards the interior) is also partly spiral.

Fig. 8B. From the same section, showing a spiral trachea (*tr.*) imbedded in the middle of the pith; *p.*, elongated pith-cells. Both figures × 165. C.N., 419E (from Mr. J. LOMAX) (see p. 87).

PLATE 14.

Spencerites insignis.

Fig. 9. Part of a radial section of a peduncle, to show the middle cortex. *sh.*, sheath of elongated cells surrounding a leaf-trace bundle; *l.c.*, lacunar middle cortex, consisting of irregular interwoven trabeculæ. × 70. C.N., 419E (from Mr. J. LOMAX) (see p. 88).

Fig. 10. Part of tangential section of an axis to show a leaf-trace bundle passing through the outer cortex. *x.*, xylem of bundle; *sh.*, bundle-sheath. The larger surrounding cells are cortical. × 165. C.N., 624D (from Mr. J. LOMAX) (see p. 89).

Fig. 11. Part of the radial section of a strobilus, figured as a whole by WILLIAMSON, "Organization," Part XIX., Plate 7, fig. 50. The sporangium shown here is the lowest on the left. *c.*, cortex of axis. Two sporophylls (*sph.*) are shown, the lower incomplete. Each contains a vascular bundle; *sm.*, sporangia; the lower is shown complete and is filled with winged spores; *a.*, point of attachment of the sporangium to the distal part of the sporophyll. The rest of the sporangial wall is perfectly free. × 45. C.N., 624B (from Mr. J. SPENCER) (see p. 89).

Fig. 12. Detached sporophyll, seen in radial section. In the tissue of the large lamina, the vascular bundle, *v.b.*, is seen at two places. *sm.*, base of the sporangium, inserted on the upper surface of the lamina at *a.*; *s.t.*, torn fragment of the pedicel, bent upwards. Compare WILLIAMSON's figure, in "Organization," Part XIX., Plate 7, fig. 50. The sporophyll lies close to the cone to which it belongs. × about 50. From a slide in the CASH Collection (*Lepidodendron Spenceri*, II.) by Mr. J. SPENCER. The section is from the cone shown in WILLIAMSON's figure above cited (see p. 90).

Fig. 13. Part of transverse section of a strobilus to show sporophyll and sporangiums *ax.*, outer limit of the cortex of the axis; *sph.*, sporophyll, shown both in its proximal and distal part; *sm.*, sporangium, containing winged spores; *a.*, attachment of sporangium to distal end, *sph.'*, of sporophyll. × 45. C.N. 626 (from Mr. J. Binns) (see p. 90).

Fig. 14A. A single spore, seen in section. *w.w.*, the wing; *r.*, one of the radiating ridges, marking the line of junction with the sister-spores; *c.b.*, cellular or vacuolated body in the interior of the spore. × 265 (see pp. 91 and 92).

Fig. 14B. A tetrad of spores seen in section, showing the position of the wings. As the arrangement is tetrahedral, only three spores are seen in one plane. × 150. Both Figs. from C.N. 624B (see p. 91).

PLATE 15.

Fig. 15. *Spencerites insignis.* Figs. 16–19. *S. majusculus.*

Fig. 15. *S. insignis.* Abortive sporangium. *sph.*, part of sporophyll to which sporangium is attached; *sm.w.*, sporangial wall. The interior is occupied by a dark, contracted mass, showing some traces of cellular structure. × 110. C.N. 626 (see p. 93).

Fig. 16. *S. majusculus.* Sporophyll in radial section. This is from the left hand side of the section shown entire in Plate 12, fig. 2. *ax.*, external tissue. of axis; *sph.*, pedicel of sporophyll; *sph.'*, its lamina; *v.b.*, vascular bundle; *sm.*, sporangium (containing spores) inserted on the sporophyll at *a.* × about 40 (see p. 96).

Fig. 17. Part of a transverse section of the strobilus, showing stele and inner cortex. *px.*, *px.*, protoxylem-groups, of which there are about thirty in all; all the tissue to the inside is wood; *ph.*, remains of phloem; *l.t.*, leaf-trace bundles passing through inner cortex; *sh.*, sheaths surrounding the bundles, where they traverse the decayed middle cortex. × about 40. C.N. 624C (from Mr. J. Spencer). This section is practically identical with that shown in Plate 12, fig. 1 (see p. 95).

Fig. 18. Part of sporangial wall, seen in surface view. × about 70. C.N. 624C (see p. 97).

Fig. 19. A. Part of sporangial wall, seen in section. × 150. C.N. 624G.
B. Spore seen from the side. *w.*, wing. × 150. C.N. 624G.
C. Spore seen in oblique section. *w.*, wing. × 150. C.N. 624C.
D. Tetrad in side view; only two spores visible. × 150. C.N. 624C.
E. Tetrad in end view, showing all four spores. × 150. C.N. 624C.

IV. *On the Development of Marsupial and other Tubular Enamels, with Notes upon the Development of Enamel in General.*

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[PLATE 16.]

IN the year 1849 my father, the late Sir JOHN TOMES, (1) described the structure of Marsupial enamel, showing that the enamel was penetrated, more or less richly, by tubes running into it from the dentine, a thing unusual in other Mammalia. But, in the Marsupials, with the solitary exception of the Wombat, it is universal, although in some, as for example in *Petaurus*, only a few of the tubes enter; and in the Dasyuridæ they are far less abundant, and traverse a smaller thickness of the enamel than in the Macropodidæ.

In the latter, the tubes are exceedingly abundant, most of the dentinal tubes being apparently continued into and through the greater part of the thickness of the enamel; they become finer as they approach the surface, and none of them quite reach it; sometimes an enamel tube is connected with two dentinal tubes, and sometimes (rarely) the converse is the case.

Amongst other Mammals this character is met with occasionally; it may be well seen in the Hyrax (Plate 16, fig. 1); in some Insectivora, notably in the Shrew; in the Jerboa, and in a few other Rodents; whilst in the human subject it may be rarely found, but only in a rudimentary condition (fig. 2).

The facts that the tubes do not reach to the exterior of the enamel, even in *Macropus*; that the penetration is variable, even amongst the Marsupials; that it does not exist at all in the Wombat, and that the character reappears sporadically amongst other Mammals, would seem to render the inference justifiable that striking, and in some respects anomalous, as the character is, it cannot depend upon any very radical difference in the developmental process from that which results in the formation of an ordinary solid enamel.

This inference is borne out by the investigations to be related, which prove to throw much light upon the development of enamels other than those of Marsupials. In those Marsupials in which but few tubes enter the enamel, there is often little or no dilatation at the point of passage, nor is there any marked deviation in direction, but in the Macropods there is usually a well-marked dilatation at this point, and there is usually also a sharp bend; there is, in fact, what might almost be described as a clumsy joint; this is noticeable, though to a less extent, in Hyrax.

In *Macropus* there is also a peculiarity in the course of the tubes in their passage through the enamel, at all events in certain regions of the tooth; not only do they pursue gently curved courses, but about one-third of the distance between the surface of the dentine and that of the enamel, they all simultaneously take abrupt bends in more than one plane, which brings them into a course sometimes almost circumferential to the long axis of the tooth; hence, on the same slide they may be seen both in longitudinal and transverse section.

This peculiarity proved to be of great service in unravelling the nature and position of the tubes, as it was possible thus to check the appearances seen in longitudinal section by those apparent in transverse section at closely-adjacent points.

My father (2) had discovered that if a section of a Kangaroo's tooth be ground thin and then submitted upon a slide to the action of an acid, the tubes, or as he supposed, the dentinal fibrils ('Phil. Trans.,' 1856) could be seen hanging out as a fringe from the edge of the dentine, the intervening portions of the enamel having been dissolved. In repeating his experiment I found that the tubes so isolated stain readily with nigrosin (as do also the sheaths of Neumann in the dentine), and that the tubes somewhat readily part from the dentine, remaining upon the slide as a more or less tangled mass, waving about in the fluid; but they cohere strongly together by their enlarged ends where they have touched the dentine. They also resemble the sheaths of Neumann in being resistant to the action alike of acids and of alkalis.

Whether, like the dentinal tubes, they consist of a resistant sheath containing a softer fibril, or whether they wholly consist of the resistant material, has not been shown; but, although the enamel tubes are larger than those of the dentine, it is difficult to get coloured fluids to enter them.

It might have been supposed that it would be a very simple matter to determine the position of these tubes in completed enamel, and to say whether they lay in the interior of the prisms or between them, but as a matter of fact it proved to be very difficult.

For in proportion as the tube system is highly developed, so do the enamel prisms cease to be distinct; indeed, they can hardly be seen at all in those parts of the tooth where the tube system is richly present.

In addition to this, the tubes, like the tubes of dentine, and, indeed, like most enamel prisms, pursue a spiral course, like a corkscrew pulled out until it is nearly straight; hence, even in very thin sections, they appear to wind about with the smallest alteration of focus of the microscope.

It is, however, noteworthy that their spiral excursions do not exceed in amplitude the width of an enamel prism, so that the appearances seen in ordinary ground sections would be equally consistent with their winding along in the interior of the prisms, or with their winding round their circumferences in the interstitial substance.

Von Ebner (5) considers that they are certainly between the prisms, an opinion shared by Dr. Paul (10). But, after devoting a great deal of time to the elucidation of this point, I am unable to agree with these observers, and I believe them to lie in the interior of the prisms, a conclusion arrived at alike by the study of completed enamel and of its development.

If a section be ground thin (till it is not much more than 5 μ thick), a troublesome thing to do, owing to the brittleness of enamel, and then very slightly washed with acid, the interstitial substance is acted upon more quickly than the prisms themselves, and the latter come more prominently into view as clear spaces with sharply-defined outlines; but the tubes often cannot be seen at all in sections so treated.

If such a section be stained with nigrosin, the interstitial substance takes the stain, while the prisms themselves do not, but the stain is not very deep, and the substance has a dotted or granular appearance. At the same time, other finer lines, more darkly stained and much more sharply defined (fig. 10), come into view, and these are seen to run in the middle of the prisms, but only for short lengths; by alterations of focus, however, they can be traced further, and it can be seen that their apparent disappearance is due to their following spiral curves, so that only short lengths lie in any one plane.

They are found to wander as far as the interstitial substance, and then to return; moreover, in fortunate places, where the prisms happen to be cut transversely, a dark dot is seen in the centre, or near it, in each mapped-out area (fig. 3). I have, however, only been able to see this last-mentioned appearance in that part of the enamel which lies very near to the dentine, where the tubes are largest.

Although much has been written upon the development of enamel generally, I am not acquainted with any detailed published account of the development of Marsupial enamel, nor, indeed, of any of the forms of tubular enamel.

The material upon which the observations to be recounted have been made has been very kindly placed at my disposal by the Zoological Society, through the kindness of Mr. Beddard, and by Mr. Woodward, of the Royal College of Science; to the latter I am also much indebted for the use of several beautiful serial sections, prepared by him with another end in view, namely, the investigation of the succession of the teeth in Marsupials. My material consisted of embryos of Macropods and of Hyrax, but unfortunately it is almost impossible to procure Marsupial embryos in first-rate histological preservation, as they are apt to have lain in the pouch for a time after their death, and this has added much to the difficulty of getting good sections.

The problem of the method in which the tubular enamels are built up seemed an interesting one, as it was difficult to imagine in what way the epiblastic enamel could become penetrated by outgrowths from the mesoblastic dentine, especially when it is remembered that the first thing formed is a thin layer of dentine, in which are contained only the fine terminations of the dentinal tubes, so that the enamel is at the very earliest period cut off from any communication with the dentine pulp, save through these fine canals and their contained fibrils.

To meet this difficulty Dr. PAUL (10) has suggested that tracts of dentine matrix enter and grow out into the enamel, carrying with them the dentinal tubes; but this explanation I am unable to accept for reasons which will become sufficiently clear. But I may say at once that I have come to the conclusion that the tubes of the dentine cannot, in the strictest application of the terms, be said to enter the enamel at all; it is true that the tubes in the enamel are continuous with those of the dentine at the point of junction of the two tissues, but those which lie in the enamel are wholly and entirely a product of the enamel organ, and cannot, therefore, be properly termed "dentinal" tubes.

I have been unable to discover the smallest difference between the enamel organs of Marsupials and those of other Mammals prior to the commencement of calcification.

The first change observed is the formation of a thin layer of dentine, which differs from that ordinarily found in that it has no granular layer, but the dentinal fibrils are continued right out through it to its surface. If it so happens that in cutting the section, or from a little shrinkage in preparation, the enamel cells are parted from the thin first-formed layer of dentine, each enamel cell (hereafter called ameloblast) is found to be furnished with a process, the so-called Tomes' process, described years ago by my father (fig. 6).

At the earliest stage the free extremities of the Tomes' processes are somewhat clubbed, and tend to cohere by their edges; these enlarged ends seem to be concerned in the formation of the thickened joints already alluded to (p. 108), and they account for the cohesion of the tubes at the dentinal surface of the enamel when isolated by the use of an acid. At this period the Tomes' processes seem to become closely applied to, and to perhaps unite with, the terminations of the dentinal fibrils, but they become so quickly imbedded in pits of semi-calcified material that this is difficult to make out with certainty.

As regards their taking stains they always behave precisely as does the plasm of the ameloblasts, of which they are obviously a continuation; and in sections which are very thin, and which happen to hit the axis of a cell and its process, there is no appearance of cell membrane across the end of the ameloblast, but, on the contrary, its interior is continued without break into the process (figs. 6, 8 and 11); the nuclei of the ameloblasts lie near to the further ends of the cells, and are always much more deeply stained than the plasm of the cells.

The Tomes' processes are soft and extensile, so that when the ameloblasts are displaced they may be drawn out into thin threads (figs. 5 and 8), which renders it improbable that they have any membranous investment on their sides, although their sharply bordered outlines look as though they had one.

At any but the very earliest stage in development the Tomes' processes are artefact; that is to say, they are short portions of a much longer fibrillar process broken off at a certain uniform distance from the ameloblast, because at this point the impregnation with lime and perhaps other changes have rendered them harder.

The Tomes' process is always, in my preparations, of smaller diameter than its parent cell, in the axis of which it lies, but I am unable to say how far this diminished diameter is due to the drawing out of an extensile substance, or to its shrinkage under the action of reagents; if it could be seen, which it cannot, in a specimen not treated with any reagent, it is probable that it would be nearly or quite of the full diameter of the ameloblast, which about corresponds in size ($3 \cdot 5\ \mu$ to $4\ \mu$) to the prism of completed enamel.

The next appearance to which attention is directed, is one that is exceedingly conspicuous in the formation of Marsupial enamel; it is that of a honeycomb, the partitions of which stain strongly with almost all stains, so that the youngest layer of enamel appears to be full of holes or pits (figs. 5 and 8).

The appearances commonly seen are those represented in figs. 5 and 8, but these sections are more or less oblique to the axes of the pits; if the section happens to more closely coincide with their axes, the appearance shown in fig. 11 is seen, where the Tomes' processes are seen to enter and fill up the pits.

To the exact relations of this honeycomb to the ameloblast process I shall have occasion to recur later; for the present, it will suffice to point out a peculiarity in the honeycomb, which is, that it is most conspicuous at a certain stage of enamel formation, that is to say, near to the ameloblasts, but that in the somewhat older enamel it is lost and cannot be seen at all.

This, which is at first sight puzzling, is, nevertheless, easily susceptible of explanation; it is a familiar fact to every student of calcification, that just upon its border line it is very common to meet with a half-calcified material which is very resistant to reagents, and which is very possibly a form of Harting's calcoglobulin (4). Such structures are to be found forming the linings of the dentinal canals as Neumann's sheaths, round the lacunæ of bone, round the Haversian canals of bone, and, as a fenestrated membrane on the surface of developing human enamel when it has been treated with an acid.

But when calcification has proceeded a little further, it loses this power of resistance and dissolves in acids. So that in the case of enamel, we have first the coherent ameloblasts, then a short region in which the Tomes' processes stand isolated from one another, then the honeycomb; and, lastly, in the region of older enamel, isolated fibres occur again in these decalcified sections of tubular enamel, though had an enamel with solid prisms been under observation, nothing at all would have remained here.

But in the case of a Macropod enamel, long fibres, extending in favourable sections through the whole thickness of the enamel formed and reaching to the dentine, are seen (fig. 9). I use the term fibres for want of a better, but it must not be thought to imply that they have any distinctly fibrous structure; indeed, I can distinguish no structure in them.

The existence of fibres in growing enamel was described by Dr. ANDREWS (12), in a valuable paper, at the conclusion of which he writes: "I am led to believe that there probably exists in developing enamel, as has already been found in developing bone and dentine, a fibrous substructure on and between which the enamel is deposited. After the enamel is wholly formed, its existence seems to be wholly blotted out in the dense calcification of the tissue." This statement, so far as it goes, I can wholly confirm, so far as solid enamels are concerned. He, however, imagined that they proceeded from the cells of the stratum intermedium, which is certainly not the case.

The fibres are beautifully seen in some of Mr. LEON WILLIAMS' photographs, but their full significance has not been recognised owing to their speedy disappearance in the formation of most enamels. In Marsupials, however, owing to the retention of a canal down the axis of the enamel prism, they persist, and can be more effectually studied. When the ameloblast processes have not been torn off at the level of the honeycomb region, they are seen to start out from the axis of each ameloblast, then at a little distance from it to be laterally glued together (fig. 7), and then to become distinct again and to run on to the dentine, getting smaller and more distinct from one another as they go, and sometimes showing very plainly the spiral turns characteristic of the tubes in the enamel, which indeed I believe them to constitute. As confirmatory of the view that the fibres calcify centripetally may be mentioned the fact that within certain limits the older the enamel, *i.e.*, the further from the ameloblasts it lies, the smaller do the fibres, as seen in decalcified sections, appear.

It has been pointed out by Mr. LEON WILLIAMS (14) that the long axes of the ameloblasts in many animals by no means correspond with the direction of the prisms of the completed enamel. This is perfectly true, but the direction of the fibres does; hence these often form an angle with the ameloblasts from which they spring.

The ameloblasts stand, roughly speaking, at right angles to the surface of the dentine. That portion of the fine fibre which when broken off is called a Tomes' process, starts in the same direction, but in many places begins to turn off very abruptly about 6 μ from its parent cell, and afterwards undergoes other changes of course (fig. 9). How these changes of direction are brought about there is nothing to show, but I am satisfied that they correspond exactly with the course of the enamel prisms in the finished tissue. And it is possible to trace the fibres into continuity with the plasm contents of the ameloblast (fig. 6), so that we can safely say that each ameloblast sheds off from its open free end, or is converted into, plasm which consolidates into a fibre, and that this fibre runs continuously through the whole thickness of the enamel.

To return to the honeycomb structure, it appears that the membranous-looking exteriors of the fibres are fused with the partitions of the honeycomb, as is indicated by that portion of the fibril which intervenes between the ameloblast and the honeycomb shrinking a little so as to leave interspaces, whilst its attached ends do not shrink (fig. 11). This is also well seen where the fibrils have been drawn out, in which case the end of the fibre attached to the honeycomb retains its full diameter, that attached to the ameloblast a considerable part of its diameter, whilst the intervening portion is drawn out into a mere thread (figs. 11 and 8).

Hence it is difficult to resist the conclusion that the septa of the honeycomb are formed by calcification, or by changes preparatory to calcification, in or round the peripheral portions of the fibres, and that this progresses inwards towards their axes, *stopping short, however, in the tubular parts of a Marsupial enamel of reaching their centres, and so leaving a central canal down the axis of each fibre which remains uncalcified.*

In transverse sections of the honeycomb the spaces may sometimes be seen to be occupied by a less deeply stained circular body (fig. 4), though this often does not quite fill the hole. This, however, is probably due, not to such being its normal condition, but to its having shrunk a little where it is still soft, whereas the septa have become rigid, being further advanced in calcification. Oblique sections, though at first sight a little more confusing, lend themselves to the same interpretation.

The ameloblasts, when cut obliquely, are difficult to define, though their nuclei remain conspicuous objects; a little way from their ends the cells of the honeycomb show as ovoid openings (fig. 12), while beyond (above in the figure) the tissue appears more solid.

In the openings of the honeycomb, dark bodies, the fibres cut across, occur in many places, whilst in others they have fallen out; but enough remain to show their identity with the row of oval dark bodies, which, with light interspaces, constitute the older, more solid portion; this is especially well seen in fig. 12, in which it is obvious that the succession in series of dark ovoid bodies are not markings in an individual fibre, but consist of a series of parallel fibres cut across obliquely.

This same appearance is seen in one of Mr. LEON WILLIAMS' photographs (fig. 83 of his paper), though he appears to interpret it differently.

It will be noticed that in these oblique sections the partitions of the honeycomb are well stained, as they usually are; but as we progress further into the more formed enamel the corresponding areas become light, and it is the contained fibre alone that is stained. In fact, the septa have almost disappeared under the action of the decalcifying acid; and, still further, in yet more developed enamel, they quite disappear, leaving the fibres free.

In other words, the most calcified portions dissolve in acid, those less calcified remain and take the stain; while in completed enamel the interstitial parts remain the most susceptible to solution by acids, as is exemplified by the effect of washing a ground section of enamel slightly with weak acid.

Conclusions as to the Development of Marsupial Enamel.

Each ameloblast gives origin to an axial prolongation of its own interior plasm.

The ameloblast is not itself actually calcified, as was formerly supposed by many observers, myself included, but this fibrillar prolongation of its plasm does calcify; hence it seems probable that a single ameloblast gives rise to the whole length of an enamel prism, itself receding as the enamel grows thicker.

In each individual fibre calcification goes on from without inwards, leaving, during the formation of the greater part of the thickness of the enamel, a central tract soft and uncalcified.

Ultimately, however, as the exterior of the enamel is approached, the axial canal becomes smaller and smaller, and finally thins out to nothing, so that a solid prism is the result. This occurs earlier in the process in some Marsupials than in others.

The tracts of calcification belonging to each fibre do not fuse completely with their neighbours, but a small amount of interstitial calcified material is poured out between them.

Nevertheless, it is not at all certain that each fibre has a membranous sheath, although it seems as if their outer were more dense than their inner portions. This theory of the calcification of enamel is quite in accord with the views expressed by Dr. SIMS WOODHEAD (11). He holds that calcification is in a measure a sort of degenerative process, the stages of which are that the active plasm becomes a "formed material," and that in this lime salts, brought and prepared by the still active tissues in its immediate neighbourhood, are deposited, their deposition taking place by physico-chemical processes, which he compares to dialysis.

One difficulty suggests itself in the acceptance of the theory here advocated, which involves the laying down of the enamel prisms as an organic matrix; and this is the chemical composition of enamel.

I have shown elsewhere (15, i.) that the amount of organic matter left in finished enamel, at all events in that of the Elephant, Horse, and Man, is exceedingly small, far less than the three to four per cent. usually given in analyses; and it is hard to understand what becomes of the organic matter which must certainly at one time have been present. I have not succeeded in isolating a sufficient quantity of Marsupial enamel to ascertain with certainty what proportion of organic matter remains in it, but I have met with indications that it is at all events, just as might have been expected, materially more than in the other Mammalian enamels. It is, of course. possible that the fibres, continuous though they are with the plasm of the cells, may have already become themselves poor in organic matter. And it is not clear why, unless each fibre has a limiting membrane, the contiguous fibres do not completely fuse with one another; in the most perfect human enamel the prisms are not exceedingly distinct prior to the application of a reagent, but washing with weak acid always renders them so, and it is seen that there is a small amount of interstitial substance which is more quickly acted upon than the prism itself, just as in Marsupial enamel.

I do not propose in this paper to enter into the vexed question of the precise mode in which the lime salts are prepared and deposited, as to do so would extend it to an undue length; whether VON SPEE (7), ANDREWS (12), and WILLIAMS (14) are right in believing that globules of a semi-fluid material rich in lime are formed within the ameloblasts, and shed out from their ends, I am not prepared to say. Several of the photographs and drawings which illustrate this paper, show very plainly the appearance of those oval or spherical forms in the cells upon which their view is founded (figs. 5 and 8).

And a photograph taken by me, many years ago, of the developing enamel of a species of *Halmaturus* seems to lend some support to the idea that there may be some such material, as a vacuolated appearance shown in it is confined to a particular series of sections, and suggests the idea that it has been produced by some sort of coagulation of a semi-fluid material rather than that it is a real histological tissue.

There are, however, some other appearances to which passing attention may be called, as they are shown in the illustrations to this paper.

The ameloblasts vary much in length; of course it has long been known that the enamel organ is more extensive upon the tooth germ than is the area upon which enamel is to be developed, and that the ameloblasts where no functional enamel is going to be formed are short and small.

This variation in the length of the ameloblasts has been alluded to by ALBERTINA CARLSSON (13), when describing the early tooth germs of osseous Fish, but she speaks with reserve as to its significance.

I have noticed, however, that they undergo a great increase in length in Marsupials even after calcification has commenced.

Thus, at first, where but a thin layer has been formed, they are often not more than 30 μ long, whereas in the same or neighbouring sections, where the process is in full swing, they are as much as 45 or 50 μ long; so far as it goes this would point to a single cell forming the whole length of the prism.

Again, the appearance of the nucleus is often peculiar; its usual form is that of an oval, quite filling up the cell at the place it occupies, near to the distal end of the cell.

But, in so large a number of sections as to render it unlikely that it can be due to any accidental cause, it has a square or even a concave end towards the forming enamel (fig. 9), while from the horns of the crescent thus seen in section there appear to be processes running down towards the free end of the cell, though of the existence of these delicate fibres I am not very certain.

The plasm of the cell also has a markedly reticulate structure, the threads running principally in its length, but I have not succeeded in connecting them definitely with the developmental process (figs. 5, 6, and 8).

It seems possible, if the nuclei do thus give origin to threads, that their concavity towards the forming enamel may be due to their being more tied at some points than at others, and so assuming this form during their progressive recession as enamel is being formed.

The views advocated in this paper are quite at variance with those expressed many years ago by the late Professor HUXLEY (3), who believed that the enamel cells or ameloblasts were separated from the forming enamel by a membrane, so that, as calcification took place upon the opposite side of this membrane from that occupied by the cells, they could not take any direct part in the process.

This view has not, more especially of late years, had many adherents, and there is amongst recent writers a tolerably complete consensus of opinion that the enamel cells do take a very primary and active part in the process.

Miss NUNN (6) arguing to a considerable extent upon certain appearances which she had observed in the developing teeth of Plagiostomes, supported Professor HUXLEY'S view, but in some particulars carried it yet further, the following being her conclusions :—

1. The *cuticula dentis* is formed by the metamorphosis, either in whole or in part, of the enamel cells, which have nothing whatever to do directly with the formation of the enamel. In its early stages the cuticula has frequently been considered as " the newly formed layer of enamel " and also as the basement membrane.

2. The basement membrane may be demonstrated upon the surface of the tooth papilla and upon the tooth in all stages of development. It becomes calcified with the other hard tissue of the tooth and cannot be separated by acid.

3. The enamel, like the dentine, owes its origin to the odontoblasts, the processes of which, in an early stage, may be traced quite up to its outer edge.

The nature of the *cuticula dentis*, so long in dispute, seems to have been tolerably conclusively settled by the recent researches of Dr. PAUL (9), who considers it to be a thing formed after the completion of the whole thickness of the enamel, and non-existent at any earlier stage in the process. From the shape, size and general appearance of the cell forms which can be traced in it (in describing which he has been to some extent anticipated by Miss NUNN), he concludes that it is formed not by the ameloblasts, but by the cells of the external epithelium of the enamel organ.

If this be the case (and even if his conclusions be not in all respects correct), it would appear that Miss NUNN considers as one and the same thing structures which most observers hold to be two perfectly distinct things, namely, the membrane which can be raised by acid from the enamel of a complete but unworn tooth (NASMYTH'S membrane or *cuticula dentis*), and that which can be raised by acids from the surface of enamel only during its development.

The latter is not a continuous sheet (15, ii.); at least it is a much perforated sheet, the perforations corresponding in size and position with the ends of the forming enamel prisms, and it is, I believe, entirely artefact, that is to say, it is merely a certain stage in the development of the enamel, of small vertical thickness in most enamels, but, in the form of the "honeycomb" of this paper, of greater thickness in Marsupial enamel.

Nothing which is contained in Miss NUNN's paper appears to me to really militate against this view, and the long fibrillar processes demonstrated in the present paper, which are without question continuous with the ameloblasts, go to prove that there cannot be a membrane separating the ameloblasts from the forming enamel, and also that the ameloblasts do take a most active and direct part in enamel formation.

Miss NUNN's third conclusion, based apparently upon what she had seen in developing Plagiostome teeth, that the enamel owes its origin to the odontoblasts, is startling in being at variance with the almost universally accepted view that the enamel is epiblastic and the dentine mesoblastic in origin.

Nevertheless, from investigations which I commenced only after this paper was in the hands of the Royal Society and which I hope shortly to publish, I believe that, so far as the so-called enamel of Plagiostomes is concerned, she was nearly right, and had hit upon a significant discovery, in which she was partly anticipated by HERTWIG, but which appears to have been overlooked by most subsequent writers.

But so far from this observation being applicable as an argument as to the manner in which enamel generally is developed, I consider that it is to be interpreted quite differently.

The existence of a strongly differentiated layer upon the mesoblastic dentine papilla of Plagiostomes, which HERTWIG and she have quite rightly, though not in much detail, described, I can confirm, and it does certainly participate in the formation of the so-called enamel of these creatures.

But I think that this goes to show that their so-called enamel is not fully homologous with that of higher vertebrates, for neither this layer itself nor anything corresponding to it has any existence in the Mammalian tooth germ.

And, indeed, the suspicion that the enamel of Plagiostomes was not fully comparable to that of Mammals seems to have occurred to writers who have only investigated it in its completed condition; thus the late Sir RICHARD OWEN gave to it a special name, that of *Ganoin*, and more recently JAECKEL (16) speaks of it as a very low form of enamel, and proposes for it the name *Placoinschmelz.*

But I have only very lately adopted the view that the enamel of Plagiostomes is not fully homologous with that of Mammals; and, indeed, in this paper, as originally presented to the Royal Society, I had drawn comparisons between the tubular enamels of Marsupials and of Plagiostomes which I no longer consider to hold good in their entirety.

The theory of enamel formation here advanced, whilst reconcilable with the figures given by RÖSE (8), is not quite in accord with the views recently advocated by LEON WILLIAMS (14), who is of opinion that the enamel prism (or rod as he generally styles it) is the thing first formed, and that the prisms are at a later stage of the process fused together by an at first semi-fluid material, which runs in between them; whereas the illustrations which accompany this paper would indicate that the interstitial substance and the peripheries of the prisms are the first things to be formed.

And whilst I admire the beauty of his specimens and of the photographs which illustrate his paper, I cannot help thinking that if he had had Marsupial enamel under observation, he would have drawn somewhat different conclusions as to the development of enamel generally.*

The view that enamel formation essentially consists in the centripetal calcification of preformed fibres, is applicable to all enamels, and serves to render intelligible many facts that were otherwise difficult to understand. Tomes' processes and the existence of a thin sheet of young enamel, which was perforated, have long been recognised both in human and other Mammalian enamels, and, indeed, traces of a honeycomb structure may often be seen. So also have the soft fibres been described by **Andrews** and others, but the full significance of these several structures has not been recognised, owing to their being so speedily obscured by the complete solid calcification of the enamel prism.

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* Mr. LEON WILLIAMS (14, i.) writes: "If we look closely at the last layer of developing enamel shown at *d*, we shall see that it contains a row of globular bodies of very regular and uniform size. These are manifestly identical with those seen along the edges of the enamel in the acid-treated specimens shown in figs. 33 and 35 of this paper. They are quite distinct from the masses of calcoglobulin, such as are seen at C, in fig. 38. In fact, they are often, I may say generally, obscured by the melting together of the large irregular masses. The enamel rods are built up by the successive, rhythmical orderly deposit of these bodies of uniform size, which I shall henceforth denominate the enamel globules. The larger, more transparent, and irregularly sized bodies of calcoglobulin melt or flow together to form the interprismatic substance "(p. 36).

"There are two distinct products of the enamel-forming organ. One of these products, from which the enamel rods are built up, is formed by the ameloblasts, and is probably a direct nuclear formation. In the enamel cells it takes the form of globular bodies containing granules, sometimes arranged with more or less order, so as to resemble the nucleus of the cell. In the formed enamel rod these globular bodies are more or less compressed into disk-like shapes, and are sometimes nearly or quite melted into one another. Simultaneously or alternately with the deposit of the globular bodies a translucent substance like albumen in appearance is seen passing out of the ameloblasts. This substance is probably taken from the blood by the secreting cells of the *stratum intermedium*, and evidently contains the mineral matter of which the completed enamel consists. As the globular bodies pass from the ameloblasts they are seen to be connected with plasm strings, which strings can often be plainly seen in the body of the ameloblasts. The globular bodies are also often seen connected literally by strings or projecting processes. Around the skeleton thus formed, which constitutes the real structure of enamel, the albumen-like substance flows, supplying the cement substance and probably the mineral matter, for the calcification of the whole" (p. 78).

But Mr. LEON WILLIAMS in his earlier writings upon the subject (14, ii.) came, in my opinion, very close to the true interpretation of the development of enamel, for he there wrote that in teased-out enamel cells a fibre runs out from the end of the cell, and that as the formation of enamel progresses the cells recede, leaving within the formed enamel what appears to be a fibre of living matter in the centre of the enamel prism.

Once grant that a manner of calcification, resulting in the formation of tubes, is the normal and indeed the universal procedure in the first instance, and that the differences are solely in degree; that is to say, that the tube system is retained for the greater part of the thickness of the enamel, but is abandoned in favour of a solid calcification in the outermost part of the enamel, in Marsupials, and that in the rest of Mammalia the tube condition is very transient, the fibres speedily becoming solid prisms, then the difficulty of accounting for the occasional occurrence of tubes in human enamel (fig. 2), and for the reappearance of the tubes in certain Rodents, Insectivora, and in Hyrax (fig. 1), disappears, and it is not necessary, as heretofore, to seek a teleological interpretation for a structure that we cannot see to be in any way advantageous: it becomes simply the retention of a stage of development through which all alike pass, and which some retain and others do not.

The calcifying fibres seem to present some parallel with ordinary osteogenetic fibres, and perhaps, in respect of their imperfect calcification, with **Sharpey's** fibres, but they stand alone in being the product of epithelial cells, and also perhaps in being distinctly the extensions of individual cell contents.

Tubular enamels are quite common amongst Fish, but until their development has been worked out, it is unsafe to draw close comparisons with them; for at present it appears as though in them, or at all events in Plagiostome fish, a tissue which, when complete, has a good deal of resemblance to a Marsupial tubular enamel, has been formed by a developmental process by no means identical.

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Lettering Applicable to all the Figures.

a. Ameloblasts.
b. Cells of *stratum intermedium.*
c. Youngest portion of enamel on honeycomb region.
d. Dentine.
d.p. Dentinal pulp.
e. Enamel.
f. Fibrillar processes of the ameloblasts.
g. Tubes in the enamel.
h. Boundaries of the enamel prisms.
i. Enamel prisms tolerably advanced in calcification.
k. Globular bodies of von Spee and Andrews.
l. Tomes' processes.
s. Stellate reticulum of the enamel organ.

Description of Plate 16.

Fig. 1. Ground sagittal section of tooth of Hyrax; a slight bend and dilatation exists where the tubes pass from the dentine into the enamel. × 80. From a photograph.

Fig. 2. Human dentine and enamel (abnormal), showing a slight penetration of the enamel by continuations of the dentinal tubes. × 200. From a photograph.

Fig. 3. Ground section of the enamel of *Dasyurus*, near to the dentine, and parallel with its surface, so as to cut the enamel prisms transversely; slightly washed with acid. × 1000. Drawing.

Fig. 4. Section of young enamel of *Halmaturus* transverse to the cells of the honeycomb, decalcified and stained. The slightly shrunken fibrils are seen occupying the spaces. × 700. Drawing.

Fig. 5. Developing enamel of *Macropus*. The section is not quite parallel with the long axes of the ameloblasts, hence the cells of the honeycombed layer are opened somewhat obliquely. The ameloblasts are slightly pulled away from the forming enamel, so that their processes are drawn out and thinned down. × 700. From a photograph.

Fig. 6. Ameloblasts of *Macropus*, showing Tomes' processes and their continuations into long fibrils. At one side (the left) the section does not pass through the axis of the cell and its process, and here there is an appearance of a membrane across the end of the cell, which is absent at the other side. × 700. From a drawing.

Fig. 7. A general view of the developing tooth of *Halmaturus*. To the right, near the top, is the stellate reticulum of the enamel organ, then the *stratum intermedium*, the ameloblasts, Tomes' processes, and the longer fibrils into which they are continued. Below this comes a layer of dentine, enclosing the dentinal pulp. × 200. From a photograph.

Fig. 8. Ameloblasts of *Macropus*, showing their processes, which have been much drawn out by the displacement of the cells. Below is the honeycomb. × 700. From a drawing.

Fig. 9. Ameloblasts and their processes of *Halmaturus*. The nuclei of the ameloblasts present an angular, sometimes almost crescentic form, and their processes undergo several abrupt changes of direction shortly after leaving the cells; corresponding changes of direction occur in the tubes in completed enamel. In places the fibrils reach right across to the dentine. × 250. From a photograph.

Fig. 10. A ground section of the enamel of *Macropus*, which has been washed with acid and stained with nigrosin. The tubes are seen as short, curved, sharply defined lines, whilst the interstices of the prisms are less deeply stained. × 500. From a drawing.

Fig. 11. A somewhat oblique section of ameloblasts, their processes, and the pits of the honeycomb. In this section there appears to be some differentiation of the axial portions of the fibrils, as ill-defined dark areas appear in their centres. × 800.

Fig. 12. An oblique section through the ameloblasts, which are at the bottom of the figure; the honeycomb region; and, at the top of the figure, somewhat more advanced enamel. In this latter region many rows of parallel prisms or fibrils are cut obliquely, so that a pattern which does not belong to a single fibril or prism is produced. The interstices between them are here clear and unstained. × 650. From a photograph.

V. *On the Biology of* Stereum hirsutum (Fr.).

By H. Marshall Ward, *D.Sc., F.R.S., Professor of Botany in the University of Cambridge.*

Received November 23,—Read December 16, 1897.

[Plates 17–21.]

Several anatomical studies of this well-known and common Hymenomycete are to hand, of which the best are those of De Bary* on the general features of the young sporophore,† of Hartig‡ on the anatomy of the adult fungus and its behaviour in oak, the wood of which it destroys, of Massee,§ who treats of it in his account of the Thelephoreæ, and of Istvanffi,|| who is concerned with the distribution of the tissue systems. The only attempts known to me at cultivating *Stereum hirsutum* from the spore are those of Brefeld,¶ and these were not successful beyond the early stages of germination and development of a mycelium.

During the past year I have been engaged in cultivating this fungus in various ways on different media, the primary object having been to see if any trace of the enzyme or enzymes it must contain could be extracted, and dealt with separately. The progress of events led the inquiry in other directions, since it was found possible to obtain excellent cultures in a pure condition and bring them after some months to the development of the fructification, with the basidia and basidiospores normally matured, and as this had not been done previously, it appeared worth while to pursue the results further.**

The cultures were obtained in the first place by allowing sporophores of the fungus to lie overnight on clean glass plates, on which they deposited the spores in quantity. Some of these spores were then washed into a tube of sterile water, and drop-

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* 'Comp. Morph. and Biol. of Fungi,' English edition, p. 53.

† In the English edition, in the sixteenth line from top of p. 54, "upper surface" should be "lower surface" according to the German edition of 1866 (p. 62).

‡ 'Die Zersetzungserscheinungen des Holzes.'

§ 'Journ. Linn. Soc.,' Botany, vol. 25, pp. 107 ff.

|| 'Pringsheim's Jahrbücher f. Wiss. Bot.,' 1896, vol. 29, p. 391, Plate 4, fig. 15.

¶ 'Unters. aus d. Gesammtgeb d. Mykol.,' H. 8, p. 21.

** The fact of this successful culture was announced at the Toronto meeting of the British Association, September, 1897.

cultures and plates made with gelatine or agar containing 1 to 2 per cent. of sugar or a little raisin juice, in which they germinate readily.

The mycelia grew rapidly, and were easily isolated and grown further on various media, tubes of agar consisting of 1·5 per cent. of agar with 1 to 2 per cent. of brown sugar, and made with tap-water, yielded excellent results.

The early stages of germination of the spores were followed in detail under high powers; but, as they offer nothing new, I pass to the mycelium. A pure culture forms in a few days a thick white cushion exactly like cotton-wool, which, particularly on sugar-agar, turns yellow-brown as it ages, and appears dense and felt-like.

No further developments were obtained on these tube-, plate-, or drop-cultures; and in the course of two or three months the dried up tube-cultures showed no trace of spores or other organs of reproduction.

During the course of the experiments I transferred isolated mycelia to blocks of horse-chestnut prepared as follows:—

Pieces of the wood, about 2 inches long by ¾ inch broad and ¼ inch thick, were split from the alburnum of a stem some 10 inches or so in diameter. Each block was put into a sterile tube plugged below and above, covered with water—in some cases with 1 per cent. sugar solution—and steamed. The surplus liquid was then poured off, and the sodden block resting on the wet plug below then properly sterilised.*

A trace of the pure mycelium transferred to such a block grows rapidly, and in many cases three or four days suffice for the development of a white patch, which, in a week or so, spreads over the whole surface as a delicate felt like cotton-wool; and sections show that the hyphæ have begun to penetrate into the wood.

This white felt goes on increasing in thickness for weeks, and in from two to four months it stands up from the surface in cushion-like masses ⅛ to ¼ inch high, so that the invested wood appears to be hidden in cotton-wool (Plate 17, fig. 3).

Excepting that the primary growth was more rapid on the wood soaked in 1 per cent. sugar solution, I could detect little difference between the various blocks at the same temperature. The growth is best at ordinary temperatures (15°–18° C.), though it progresses rapidly for a time at 20°–25° C. At 30° and upwards it is distinctly poor, though I have not made exact experiments to determine the limits.

I may add that my earlier work was directed to attempts to obtain direct evidence of the enzymes which must be assumed to exist in such a fungus, and the sugar solution was added to the wood because it seemed probable that, in the destruction of wood, the splitting of glucoside-like bodies occurs, and sugars become available for food; the addition of a little sugar, therefore, would possibly accelerate the growth and activity of the fungus.

For the present, however, the hope of obtaining such proof of the existence of definite enzymes as I was seeking has had to be abandoned, though, as will be seen, plenty of indirect proof of them is forthcoming.

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* The employment of wood for certain cultures has been practised by **COSTANTIN** and **MATRUCHOT** ('Compt. Rend.,' vol. 119, p. 752).

On some of the blocks, after about three months' culture, the mycelial cushions, hitherto pure white like cotton-wool, showed yellowish patches here and there. The area of discoloration spread, the colour deepened to buff, or almost orange, and, during the fourth month, the surfaces appeared raised as thickish bosses, in some cases accompanied by tears of clear watery liquid, apparently exuding from them. As the colour deepened the bosses seemed waxy or dry, sometimes with a bloom, as if powdered with mustard or yellowish chalk (fig. 2).

I thought at first that an intruder had made its way into the culture, though it was not easy to see how this should be, considering the precautions taken. However, the regularity and uniformity of appearance of just these yellow bosses, and no other change, in one tube after another during the fourth to sixth month were not consistent with the invasion of a foreign organism.

Sections through these yellow bosses showed a dense meshwork of radiating hyphæ and innumerable minute spore-like bodies, evidently arising at the powdered surface. At first I thought a sort of conidial stage had been disclosed,* but these fresh sections examined in water were not sufficiently clear to decide any such point.

Most interesting results were obtained on cutting properly hardened and stained sections of the more prominent and somewhat waxy-looking older humps on cultures four months old and upwards, for the surface was found studded with typical basidia and basidiospores, showing that these humps were really small hymenophores.

Fig. 2 shows a group of these hymenophores on a block of *Æsculus* wood, with sugar, infected four months previously. This culture had been kept at ordinary temperatures, in the dark, from March 7 (the date of infection) to May 25, thence onwards to July 2, in diffuse daylight at the same temperatures, *i.e.*, about 15°–16° C., except on occasional hot days.

Since the same buff-yellow, waxy-looking hymenial humps appeared on tubes of the same batch kept in the dark the whole time, I cannot attribute anything to the light.

A section across one of these humps is figured in fig. 4 under a low power.

It shows three principal regions :—(1) a base or core of loose hyphæ, crossing and anastomosing in all directions, and with large interspaces: this is indistinguishable from the vegetative mycelium, the cotton-wool appearance of which is due to the air entangled in the meshes; (2) an intermediate region of much more closely packed hyphæ, radiating from this core; and (3) the densely packed palisade-like ends of these radiating hyphæ, forming the superficial hymenium.

As I understand matters, the first region corresponds to the *subiculum* of systematists,* the second to the *sub-hymenial layer*, and the third is certainly the *hymenium* of basidia and barren ends, and I shall refer to them by these names in the following analysis.

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* MASSEE (*loc. cit.*, p. 120, and Plate 46, fig. 7) describes and figures conidiophores, but I have not found anything resembling his figure.

If a portion of a vertical section is more highly magnified, as in fig. 5 (Plate 18), the *subiculum* is seen to consist of loosely interwoven hyphæ, with dark spots in the meshes; the *sub-hymenial* region shows radiating, branched hyphæ of two kinds, one of which is stained more deeply than the other; and the *hymenium* itself forms a deeply stained palisade-like layer of basidia, each with four long sterigmata bearing the spores.

Under high powers the dark spots in the *subiculum* are found to be pyriform swellings densely filled with contents which stain deeply, and are evidently developed as the swollen ends of the hyphæ (fig. 6); the conspicuous radiating hyphæ of the sub-hymenial layer are shown to be thin-walled, multiseptate filaments, with highly vacuolated contents, and branching in a sort of fan-like or falsely dichotomous manner, reminding one of the growth of many filamentous algæ. The contents stain so much more deeply than do those of the thicker-walled hyphæ in which they grow and intrude as into a matrix (fig. 7), that this system of hyphæ is sharply marked as distinct.

High-power sections, taken vertically through the *hymenium* (fig. 8), present little that is not known, but attention may be drawn to the facts that the young spores are round, and that they become more and more elongated as they mature; that the large basidia are clearly the ends of hyphal branches coming up from the sub-hymenium; and that many of the ends of the branching hyphæ remain barren. As fig. 9 shows, some of these barren ends grow out like *paraphyses* or *cystidia* here and there, but I am not sure whether this is a mere accident or an expression of the fact that, after the present crop of basidiospores is matured, these intermediate hyphæ grow forward, and develop the new hymenial layer, thus accounting for the periodic zones of growth found in older hymenophores.†

The observation that the sub-hymenium of *Stereum hirsutum* contains two kinds of hyphæ was apparently new, though the presence of a sort of laticiferous system in other species of this genus is well known,‡ and on cutting sections of the mature sporophore of specimens kindly sent me by Mr. MASSEE I find them there also, thus confirming ISTVANFFI,§ who had already figured them. They are quite evident in thin sections parallel to the surface of the hymenium, and therefore transverse to the course of the hyphæ themselves.

I am quite unable to explain in detail the significance of the pyriform swellings in the *subiculum* and the two kinds of hyphæ in the *sub-hymenium*. ISTVANFFI speaks

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* *E.g.*, MASSEE, *loc. cit.*, p. 119.

† See also DE BARY and HARTIG, *loc. cit.*

‡ ISTVANFFI and OLSEN, 'Bot. Centr.,' vol. 29, 1887, p. 373; 'PRINGSHEIM'S Jahrb.,' 1896, vol. 29, p. 391; MASSEE, *loc. cit.*, p. 121.

§ *Loc. cit.*, p. 391, and Plate 4, fig. 15.

of a *Leitungssystem* in regard to one kind of hypha, but there seems no direct evidence of function. In some sections the pyriform swellings give out branches, and present a curious formal resemblance to ganglion-cells when stained, but whether these branches run up as the hyphæ which terminate in the basidia, or as those which end like paraphyses, I cannot as yet determine. It is also very difficult to determine which hyphæ are and which are not segmented. It would be an interesting point in relation to the phylogeny of this fungus if the hyphal arms connected with the pyriform bodies end in basidia, since the view which would suggest itself to the advocates of the BREFELD school of morphology would no doubt be that the pyriform bodies are the homologues of chlamydospores. At present I can throw no certain light on this. Up to the present, moreover, I have not been able to make the sporophores grow out into the bracket shape so commonly observed in such fungi in the open; the air and space at the disposal of the imprisoned fungus are, of course, limited, and no doubt affect this matter.

As already said, the only attempts at pure cultures of *Stereum* known to me are those of BREFELD,[*] who tried nine different species of this genus, including *S. hirsutum*, but failed to obtain anything beyond the barren mycelia. He says: "Die Mycelien endeten nach langer Cultur trotz riesiger Ausdehnungen auch im Luftmycel gänzlich steril an allen secundären Fruchtformen und auch an Basidienfruchten."

This is very definite, but since BREFELD does not allow us to know what medium he employs in the culture of these fungi, no suggestion can be offered in explanation of his failures.

BREFELD says the hyphæ of *Stereum* are devoid of clamp-connections in the young mycelia grown by him, but MASSEE, in his excellent "Monograph of the Thelephoreæ,"[†] says these are probably present in all species having septate hyphæ, and figures them in the closely allied *Corticium*. They certainly appear to occur occasionally, as seen in figs. 11 and 12, but they seem to be rare.

Another point in dispute is the size of the basidiospores of *Stereum hirsutum*. They are given by MASSEE[‡] as globose, and 5 μ in diameter. WINTER also gives them as "Sporen kugelig, sehr klein."[§] ZOPF[||] describes them as cylindrical, with rounded ends, 6–8 μ long and 2–3 μ broad. COOKE[¶] makes no mention of their size or shape, nor does STEVENSON.[**] COSTANTIN and DUFOUR[††] say the spores are cylindrical, but give no measurements.

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[*] 'Unters. aus dem Gesammtgebiete d. Mykol.,' H. 8, 1889, p. 21.

[†] 'Journ. Linn. Soc.,' Botany, vol. 25, No. 170, 1889, p. 115.

[‡] 'Brit. Fung. Flora,' vol. 1, p. 131.

[§] RABENH., 'Die Pilze,' Abth. 1, p. 345

[||] 'Die Pilze,' p. 341.

[¶] 'Handbook,' vol. 1, p. 316.

[**] 'Brit. Fungi,' vol. 2, p. 268.

[††] 'Nouvelle Flore des Champignons,' 2nd ed., p. 182.

BREFELD* merely refers to "Kleine, farblose und Krumme sporen," and HARTIG† says they are *birnförmigen.*

That some of the differences depend on the age of the spores measured may well be assumed. I find them long, ovoid, or pear-shaped to shortly cylindrical, and 5–6 μ long by 3–4 μ broad, and, in order to be sure that my earlier measurements, &c., were correct, I subsequently asked Mr. MASSEE to send me some fresh specimens of *S. hirsutum*, and confirmed them on the fresh spores (in water) obtained from the hymenia he kindly selected for me.

At an early stage in the investigation sections were made of the infected blocks of *Æsculus* wood put into absolute alcohol at various dates as the work proceeded. These gave very satisfactory preparations, and showed clearly that not only the medullary rays, but the vessels, tracheids, and all the elements of the wood, are invaded, the easiest passage for the pioneer hyphæ being the medullary rays exposed on tangential sections and the cut vessels on the transverse sections.

A week suffices for the entry of the hyphæ, some of which are found to have penetrated to from 6 to 10 elements deep from the tangential face; and in a month almost the whole of the wood is invaded, and the cavities of the vessels show the hyphæ, of various thicknesses, branching and growing into tufts in all directions.

In order that no question of a possible sweeping in of hyphæ from the outside, during the cutting, should arise, I wiped off the external mycelium from the block, and then scrubbed the whole surface with a hard brush before cutting.

Moreover, as the figures show (*e.g.*, figs. 10–12), it was quite easy in many cases to trace a hypha through several cells or tracheids, especially radially, and to see that it always passes through the pits. Not only so: thickish sections showed the hyphæ in the vessels which had not been opened by the razor. The lateral extension from the medullary rays or vessels into other elements is through the bordered or other pits (figs. 11 and 12); and it is very evident, in some transverse sections, that the spring wood is invaded much more rapidly than the autumn wood of the same annual ring (fig. 13).

Excellent preparations of these hyphæ in the wood can be made by overstaining the sections in very dilute DELAFIELD'S hæmatoxylin,‡ or by GRAMM'S method with gentian violet,§ and then washing out in water and successive concentrations of alcohol before clearing and mounting in xylol Canada balsam in the usual way.

The results are even better if such sections are prepared, not from alcohol material, but from blocks which have been boiled to fix the hyphæ *in situ,* and then passed through 50 per cent., 70 per cent., 90 per cent., and finally into absolute alcohol.

The action of the fungus on the walls of the elements, especially the fibres and tracheids, is particularly evident in transverse sections of *Æsculus* wood after three to four months.

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* BREFELD, *loc. cit.*, p. 21.

† HARTIG, *loc. cit.*, p. 130.

‡ See ZIMMERMANN'S 'Botanical Microtechnique,' p. 180.

§ ZIMMERMANN, p. 185.

Thin sections show that the thickening layers next the lumen are no longer homogeneous in appearance, but have swollen and separated from the layers next the middle lamella, and lie loose in the cavity, often contorted or wrinkled in curious shapes, evidently because their prison is too small for the swollen layers (see figs. 17–19). This is particularly clear in cases where the section has passed through a pit, for the swollen layers here form a ring, broken at the pit and folded or coiled according as the severed ends abut on one another or glide one over the other during the swelling (figs. 18 and 19).

It is a common event in such sections to obtain beautiful transverse sections of the hyphæ running vertically in the tracheids, &c., and these are evidently held in position by the gelatinised swollen layers referred to (figs. 18 and 19).

Sections such as the above placed in chlor-zinc-iodine at once undergo colour changes which betray what has happened, for while the middle lamella comes out deep yellow, and the lignified layers next it a paler, but still bright, yellow, the swollen layers turn blue, often deep blue-black, but varying in hue from that to pale violet. These swollen layers, then, have been delignified, and consist entirely, or almost entirely, of cellulose. These colour contrasts are very striking and beautiful, as shown in fig. 18.

Equally convincing and striking are similar sections treated with phloroglucin and hydrochloric acid (fig. 19). The middle lamella is deep rose-red, the layers next it paler, but still distinctly red, but the swollen layers remain colourless; they contain no lignin.

The results with aniline chloride, and with other reagents for differentiating lignified membranes from those devoid of lignin, are in harmony with the above, and it becomes certain that the action of the hyphæ is to slowly delignify the walls from the lumen outwards. That this is a progressive action is clear from testing the wood at various stages. During the first month I find no distinct reactions with the above reagents, and stains, such as DELAFIELD's hæmatoxylin, do not colour the walls blue or purple, but merely brown or yellowish; but in some cases a thin lining layer is found to react in wood acted on by the fungus for six weeks to a couple of months, and the altered layer gets more and more decided as the action progresses, till the beautifully clear reactions above described are obtained after three to four months.

As the action proceeds—*e.g.*, after five or six months—the swollen layers gradually disappear from within outwards, and the layers next the middle lamella react less and less to phloroglucin and aniline chloride, and stain blue or violet in chlor-zinc-iodine or in hæmatoxylin, and may separate from the middle lamella.

The above results demonstrate in detail that the hyphæ attack the walls of the tracheids and other wood elements of *Æsculus* from within, gradually delignify them layer by layer, and then consume the swollen cellulose matrix. HARTIG had already stated in general terms that *Stereum hirsutum* acts thus in the oak, but he also says that in some cases the elements of oak wood are isolated by the middle lamella being first dissolved. Whether this depends on differences in the action on oak, or on his having some other fungus present—he employed diseased wood from the forest for his examinations, and so ran the risk of contamination—I cannot yet say, and my cultures on oak are still too young to determine the point, nor have I yet succeeded in extracting from my cultures the enzyme, which must be assumed to exist, which effects the delignification.*

Experiments were made to test the growth on other woods than *Æsculus.* Blocks of *Pinus* and of Willow were used, prepared as before, with water only, and gave the same results so far as the sap-wood is concerned, but it happened that in blocks which contained heart-wood only the growth appeared to be arrested (see fig. 1). I therefore had series of blocks cut entirely from the heart and entirely from the sap-wood of both pine and willow. In all cases the growth on the sap-wood of both proceeded rapidly, whereas scarcely any mycelium at all was visible on the heart-wood of either pine or willow. Even after three months the cultures on the heart-wood show only a sparse cobweb of mycelium, not hiding the wood, and indeed often scarcely visible; whereas the mycelium on the sap-wood, same age and grown side by side, is a thick white, cotton-wool-like cushion, completely hiding the invested wood (fig. 1).

In order to test more completely the action of the fungus on heart-wood and sap-wood respectively, I made the following cultures :—

Three tubes each of sap-wood of oak, horse-chestnut, willow, and pine, and three of the heart-wood of each, were infected in July and placed side by side and kept under like conditions—15°-18° C. in the dark.

In October, after three months of undisturbed growth, all the cultures had succeeded, and showed marked contrasts between sap and heart-wood in each case, but especially in those of oak, willow, and pine, where the differences between sap-wood and heart are most pronounced.

The mycelia in the heart-wood cultures were almost entirely confined to thin, cobweb-like, superficial growths, which scarcely obscured the view of the wood beneath, even in the most luxuriant specimens, and in many cases were so inconspicuous that the wood appeared unaltered, and no mycelium could be seen at all until close examination in an oblique light betrayed it. In these cases I am speaking of the naked eye characters.

On the sap-wood, on the contrary, the mycelium had formed a dense white felted covering, like cotton-wool, and even in the feeblest specimens the wood was entirely covered. Evidently, therefore, the fungus grows more luxuriantly in sap-wood than in heart-wood—at any rate, of the species of tree examined.

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* I use this term for the sake of brevity, in spite of the fact that lignin and lignification can no longer be regarded as the simple matters they were once supposed to be. BOURQUELOT (see 'Zeitschr. f. Pflanzenkrankh,' 1895, p. 39, for reference) finds emulsin-like enzymes in these wood fungi, which split glucosides like æsculin, coniferin, &c., into sugars and other bodies.

The same truth comes out on examining the specimens with regard to the presence or absence of young hymenia, the waxy yellow humps showing up distinctly on several of the richer growths on sap-wood of oak especially; whereas no traces of incipient hymenia were visible on the poorer growths on the heart-wood.

That light is not necessary to the development of the fungus, or of the hymenia, comes out clearly from the above. But, side by side with the series referred to, I had prepared in July an exactly corresponding series, *i.e.*, three tubes each of heart- and sap-wood of oak, willow, *Æsculus*, and pine, infected at the same time and kept side by side at 15°–18° C. in the light.

The same facts came out on examining the three months' cultures in October. In all cases the growth was luxuriant on the sap-wood, and in some cases had proceeded so far that incipient hymenia were visible; whereas on the heart-wood the mycelium was much more feebly developed, and no hymenial beginnings were perceptible.

It is, perhaps, premature to speculate on the causes of these differences, since they may reside in difference of food-materials in the walls of heart- and sap-wood respectively, in the existence of antiseptic bodies, in differences of mechanical obstruction to the entry of the hyphæ, or in other factors; but taking all observations together, I suspect that aëration—ventilation—is at the bottom of the whole question, and I am now carrying on experiments which will, I hope, settle the matter.

In this connection it may be interesting to compare the normal structure of the woods of *Æsculus, Salix, Quercus*, and *Pinus*. The latter consists, as is well known, of tracheids only, apart from a few wood-parenchyma cells near the resin passages, and since the heart-wood is full of resin, and the tracheids closed, the fungus hyphæ will have peculiar difficulty in obtaining air. Apart from other causes, therefore, I attribute the poor growth on pine to this difficulty.

In oak we find large vessels in the spring wood, and smaller ones throughout the summer wood, together with tracheids, wood-parenchyma, and fibres; moreover, the medullary rays are in part very broad, whereas in *Pinus* they are all very narrow. But in the heart-wood the vessels are rapidly stopped by tyloses, and the sap-wood is very narrow. Hence the ventilation of the heart-wood is difficult.

Æsculus and *Salix* both have small numerous vessels and much fibre, but no tracheids and very little wood-parenchyma. Whereas *Salix* forms a distinct heart-wood, that of *Æsculus* is very little, if at all, different from the sap-wood, and no doubt the much freer growth of the hyphæ in the "heart-wood" of *Æsculus* is correlated with this fact. At the same time the matter deserves further examination.

HARTIG in his work, 'Die Zersetzungserscheinungen des Holzes' (p. 129), gives an account of the destruction of oak-wood by *S. hirsutum*, but his description refers to that wood only, and to the rot as it occurs in the forest; no question of pure cultures is touched by him.

He regards the fungus as a saprophyte, though much damage accrues to living trees owing to its spreading from dead wood into the trunk.

It is significant that HARTIG found two modes of action of the fungus. In some cases, the middle lamella is first destroyed, and the elements isolated; in others, the walls of the elements are destroyed from within outwards. In the first case, the walls are delignified and converted into cellulose before final solution; in the second case, no such conversion to cellulose precedes solution.

His description does not refer to any mixture of bacteria or other fungi as being present, but it seems very likely that such would be the case in wood taken from such rotten branches, and if so, the question arises how far the changes depicted are due to *Stereum* alone, and how far to other organisms.

I have made a few preliminary experiments with promising results. Blocks of oak were prepared as usual, but before infection I poured into the tubes a few drops of water in which rotting wood, swarming with bacteria, had been crushed in a mortar, and which had been filtered through ordinary filter paper. Of course, the method of pure cultures is here abandoned, but since one of the blocks developed a crop of *Stereum* hymenophores, it will be worth while to go further into this question of possible symbiosis.

I have also tried a method of obtaining the wood blocks free from organisms without sterilisation by heat; but as yet certain difficulties have not been overcome.

EXPLANATION OF THE FIGURES.*

PLATE 17.

Fig. 1. Pure cultures of *Stereum* on blocks of willow wood, sterilised in water only, and grown for 91 days at 22° C. in the dark. The block to the left is of sap-wood, and is covered by an abundant mycelial felt, like cotton-wool; the block to the right (heart-wood) shows a much poorer development, though both were treated alike. Photographed from the original culture.

Fig. 2. A culture on *Æsculus* wood, to which 1 per cent. solution of sugar was added. The growth is 112 days (*i.e.*, nearly 4 months) old, and was kept at 20° in the dark; the small shaded patches are incipient yellow hymenial cushions. Photographed from the original culture.

Fig. 3. A culture on sterile *Æsculus* wood, to which 1 per cent. sugar solution was added, after 117 days (*i.e.*, about 4 months) at 15° C., during the first 79 days in the dark, the rest of the time in diffused light. An

abundant crop of hymenial cushions has been developed on the surface of the cotton-wool-like mycelium. Photographed from the original culture.

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* The photographs and figs. 4–11 were prepared by Mr. W. G. P. ELLIS; figs. 12, 16, and 17 by Mr. HILL; and figs. 13–15 by Miss PERTZ. I have great pleasure in recording my thanks for this help.

Fig. 4. Vertical section through one of the yellow waxy hymenial cushions of fig. 3 under a low power. Three regions are visible, viz., (1) a central basal one of loosely felted hyphæ, with small swellings here and there showing as dark points; (2) a more peripheral region, with the hyphæ more densely packed and radially directed; and (3) the outer layer of basidia covering the surface.

PLATE 18.

Fig. 5. A portion of the cushion more highly magnified, and showing the three regions still more distinctly. The intermediate layer—No. 2 in fig. 4—is composed of two kinds of hyphæ. The dark spots in the basal region are pyriform swellings of certain branches.

Fig. 6. Portion of a section taken vertically through the basidial layer under a high power, and showing basidia and basidiospores, with intervening barren filaments, in various stages of development.

Fig. 7. Part of vertical section through the central basal region of fig. 4, highly magnified, and showing the pyriform swellings on certain of the hyphæ, which are the dots in the figure referred to.

Fig. 8. Part of the region of radiating hyphæ between the basidial and basal regions last figured, and comprising No. 2 in fig. 4. The hyphæ are seen to be of two kinds. One set, with vacuolated contents and distinct segmentation and branching, stain more deeply than the faintly marked hyphæ which serve as a matrix for them.

Fig. 9. Vertical section of hymenium, showing the prolonged cystid-like paraphyses.

PLATE 19.

Fig. 10. Transverse section of *Æsculus* wood from a block infected 2 months previously, showing hyphæ in the vessels and other elements, and passing radially from one to another.

Fig. 11. Tangential section of same block, showing hyphæ of two sizes in the large vessel to the left, and smaller ones passing from fibre to fibre through the simple pits.

Fig. 12. Part of a tangential section of *Æsculus* wood exposed 4 months to the action of the fungus. Large irregular holes are to be seen in some of the walls, due to the solvent action of the hyphæ passing through them.

PLATE 20.

Fig. 13. Transverse section through *Æsculus* wood after 4 months' exposure to action of the fungus. The autumn wood of the annual ring has the walls of the elements still intact; those of the spring wood have the inner layers swollen and separating, under the action of the contained hyphæ.

Fig. 14. Portion of a radial section through same block as fig. 13. The hyphæ have invaded all the medullary ray cells.

Fig. 15. Tangential section of same.

Fig. 16. Part of transverse section of *Æsculus* wood not attacked by *Stereum*—*i.e.*, normal.

PLATE 21.

Fig. 17. Similar section of wood invaded by the fungus, and exposed 5 months to its action. The inner walls of the wood elements are seen swollen and wrinkled.

Fig. 18. Portion of a similar section in chlor-zinc-iodine. The swollen inner cell-wall layers turn blue or violet, while the enclosed hyphæ and the still lignified parts of the walls are yellow.

Fig. 19. Similar section in phloroglucin and H.Cl. The lignified parts are coloured rose-red, while the delignified swollen inner layers are not coloured.

VI. *An Investigation on the Variability of the Human Skeleton: with especial reference to the Naqada Race discovered by Professor* FLINDERS PETRIE *in his Explorations in Egypt.*

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Communicated by W. F. R. WELDON, *F.R.S.*

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[PLATE 22.]

THE present investigation was undertaken for the purpose of obtaining some insight into the variability and mutual relationships of certain parts of the human skeleton. To work at such a problem is only possible under the rarest circumstances, for the material must be at least fairly homogeneous and in far larger quantity than is ordinarily obtainable.

The valuable material with which I worked consisted of an extensive collection of skeletons belonging to the "New Race."

The race so-named has recently been discovered by Professor FLINDERS PETRIE in his explorations in Egypt, and, in his opinion, we have here "a branch of the same Libyan race that founded the Ammonite power." The period ascribed to the New Race lies between 3000 and 4000 B.C.

In discussing my measurements I considered it expedient to give some idea of the more obvious ethnological characters which the material exhibited, but it must be clearly understood that this side of the subject was not the primary object of my investigation.

The skeletons were disinterred from an ancient burial-ground covering a very extensive area, and including several thousand graves. It was situated in the district between Ballas and Naqada, some 30 miles north of Thebes, and on the west side of the Nile.

Each grave had a number assigned to it, and when a skeleton was found therein this number was written on the skull and on all the more important bones.

In some cases remains of more than one skeleton were found in a grave, and then identification of the bones into the respective skeletons sometimes became impossible.

Through the generosity of Mr. A. B. PEARSON-GEE, the skeletons were carefully

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packed and brought to England. On their arrival they were taken to University College, where the various investigations have been carried out.

A series of measurements have been made on the skulls by Mr. **HERBERT THOMPSON**, and some of the results have already been published by Professor **PETRIE*** and by Professor **KARL PEARSON**.†

In the autumn of 1895 the skeletons were most kindly placed at my disposal by Professor **PETRIE**, and I desire to heartily express to him my gratitude for the use of the bones. I also wish, in this place, to very warmly acknowledge my indebtedness to Professor W. F. R. **WELDON** for many valuable suggestions and for encouragement in this laborious undertaking, also to Professor **PEARSON** and to Professor G. D. **THANE** for kindly criticism and ever-ready help.

The measurements were taken by means of an osteometric board, kindly lent for the occasion by Professor **STEWART**. This board has two uprights, one is fixed and the other slides over a scale graduated into millimetres.

The bone is held horizontally in position, one end is placed against the fixed upright, and then the sliding upright is brought up against the opposite extremity and the measure is read off from the scale. For certain measurements it was necessary to use two projecting styles fixed to the uprights.

The measurements were recorded to the tenth of a millimetre. A small series of bones were re-measured on an independent occasion, and it was found that the mean difference between the measurements was only 0·37 mm. Such a result as this would be scarcely possible with recent bones, for the mere variation in the humidity of the air would produce a greater difference in the measures.

The observations will be dealt with in three separate sections: (1) the limb bones, (2) the sacrum, (3) the scapula; finally, we shall give a short summary of results and a few general conclusions.

I. THE LIMB-BONES.

We will first describe the various measurements made on the different bones.

1. *The Femur.*

(*a.*) The length AB (see fig. 1 in the Plate), which is the distance between the most prominent point of the head and that of the inner condyle, is called the *maximum length.*

(*b.*) The "length in oblique position" (= BF) was measured by placing the condyles flat against the fixed upright. This gives the effective length with regard to stature; it is the *oblique length.* We may express the relation between these two dimensions by finding the angle ABF, which is equal to $\sec^{-1}\frac{AB}{BF}$. Since the condyles are practically horizontal when the knees are close together, this angle will depend to a large extent upon the width of the pelvis, and so will be greater in woman than in man.

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* 'Naqada and Ballas,' 1895, p. 51.

† 'Phil. Trans.,' A, vol. 187 (1896), p. 279.

(*c.*) *The Angle of the Neck with the Shaft.*—If lines are drawn parallel to the axes of the neck and shaft, they will intersect at a point O (fig. 1). This was done on both the anterior and posterior surfaces of the bone. The central point (C) of the inner surface of the head was readily found, then the length CD was measured. OD and OC were measured on both sides of the bone and the mean was taken. It appeared to me that these dimensions were obtained more accurately by this method than if the anterior surface alone were taken.

OC = *Length of Neck + Head.*—The point O is always close to the tubercle on the trochanteric ridge and often actually on it. Some anatomists measure to the tubercle; and this measurement is very nearly equivalent to OC.

OD = *Length of Shaft.*—The angle DOC, which is the angle of the neck with the shaft, was found by the solution of the triangle DOC. This angle was determined on 140 femora.

(*d.*) *The Angle of Torsion.*—To measure accurately the real angle of torsion seemed to me excessively difficult. The angle I measured was the inclination of the neck to the horizon when the bone is held horizontally, with the condyles placed on a flat surface. This angle is certainly closely proportional to the true torsion angle and is not far removed from it. The following was the method employed. A point C′ (see fig. 2) was found on the head, such that O′C′ was parallel to the axis of the neck; O′C′ was measured. The bone was then placed in the position indicated in fig. 3, and the movable upright was drawn along till the point of the style was seen to be vertically above the point O′. The eye was placed about 2 feet above the bone. The distance between the points of the styles was recorded (= O′C″). Now, the angle $C'O'C'' = \sec^{-1}\frac{O'C'}{O'C''}$, which is equal to the angle which the neck makes with the horizon. The effect of parallax was the chief source of error in this method, but several measurements were always taken and the mean determined.

2. *The Tibia.*

(*a.*) The *maximum length* in the long axis of the bone; thus, both the spine and the malleolus are included = AB (fig. 5).

(*b.*) The length FB″, which is the distance from the centre of the inner condyloid surface to the tip of the malleolus.

(*c.*) The length FB′ measured from centre to centre of articular surfaces.

3. *The Fibula.*

The *maximum length.*

4. *The Humerus.*

(*a.*) The *maximum length* AB (see fig. 4).

(*b.*) The *oblique length* FA; this measure corresponds to the oblique length of the femur.

5. *The Radius.*

(*a.*) The *maximum length* in the long axis of the bone AB (fig. 6).

(*b.*) The distance between the points where the longitudinal axis of the bone cuts the proximal and distal articular surfaces (= FB′). This measure answers to the third on the tibia, and it would appear to give the true functional length of the bones more nearly than the other dimensions.

6. *The Ulna.*

(*a.*) The *maximum length* in the long axis including the styloid process.

(*b.*) The distance between the centre of the distal articular surface and the point where the longitudinal axis cuts the surface of the olecranon.

7. *The Clavicle.*

The *maximum length* when the bone is placed on its ventral edge.

The Determination of Sex.

This has been a matter of very considerable difficulty, and it will be seen from the tables of measurements that no decided opinion could be expressed in the case of a large number of skeletons.

Professor Thane had made a careful sex-determination on the skulls, subsequently he did the same for the hip-bones. Besides this, every bone, when taken from the packing-case and measured, was noted down as "male," "female," or "doubtful." The several bones of the different skeletons were quite indiscriminately mixed, and so each bone was pronounced upon independently. The general form or robustness of the bone, the muscle impressions, &c., were taken into account. On subsequently sorting the measurements into skeletons it was found how far the different determinations agreed. In a considerable number of cases there were no discrepancies, in other cases there was a quite clearly-marked preponderance of either "male" or "female," then the skeleton was assigned to the sex possessing the preponderance. Sometimes the sex remained altogether doubtful.

The sex-determinations having been made in this way from the long-bones, they were compared with those obtained from the skulls and hip-bones.* It was found that they agreed very fairly well with the skull determinations but still better with those from the pelvic-girdle. Consequently, as the hip-bone is the safest guide to sex, a certain degree of reliance may, I think, be placed on the male and female series which was ultimately drawn up.

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* In many cases the fragmentary skeletons having skulls had no long-bones, and *vice versâ*; similarly with the hip-bones.

The sacrum was found to be quite useless in this respect.

THE VARIATION IN LENGTH OF THE LIMB-BONES.

In Table I. we have a list of the various measures made on the long-bones. The bones of the right side were selected, except in the case of the ulna, where the left bones happened to form the larger series. The third column gives the arithmetic means of the different dimensions expressed in millimetres.[*]

The probable errors of the means are given by the formula $0{\cdot}6745 \frac{\text{Standard Deviation}}{\sqrt{\text{No. of Observations}}}$ and a rough estimate of their values may be made by mere inspection.

In the following table[†] I have compared some of the means found for the New Race with the means of the measurements made by Dr. E. ROLLET[‡] on the French. A certain resemblance is seen to exist between them; the bones which diverge most are the tibia and radius. From this we might be tempted to believe that the stature of the New Race was not far removed from that of the French; but the relation which exists between stature and the length of limb will not be dealt with in the present paper.

Bones of the right side.	French.[§]				New Race.			
	No.	Mean.	Standard deviation.	Coefficient of variation.	No.	Mean.	Standard deviation.	Coefficient of variation
Femur (maximum), ♂	50	452·28	23·72	5·425	80	459·30	25·19	5·484
" " , ♀	50	415·70	22·55	5·425	113	426·27	20·75	4·867
Tibia (excluding spine), ♂	50	368·06	17·99	4·888	85	379·70	18·77	4·943
" " , ♀	50	334·44	18·63	5·571	115	349·57	17·14	4·903
Humerus (maximum), ♂	50	330·10	15·38	4·659	62	326·18	17·01	5·216
" " , ♀	50	297·66	15·25	5·123	97	298·66	14·95	5·006
Radius (maximum), ♂	50	243·94	11·70	4·796	47	256·97	12·90	5·021
" " , ♀	50	214·86	10 95	5·096	66	233·29	10·69	4·583

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[*] The relative length of the male bone to the female bone is expressed by the "*Sexual Ratio.*" The coefficients of variation are dealt with in a similar manner. I shall here attempt no comparison of the sexual ratios in different races, as this is now being done by Professor PEARSON. It may however be noticed that the size-ratio appears to be greater in the radius, ulna, and clavicle than in the other bones.

[†] I am indebted to Professor PEARSON for the French numbers. They were calculated from the measurements made by Dr. ROLLET at the Anatomical Laboratory at Lyons.

[‡] "De la mensuration des os longs des membres," Lyons, 1889.

[§] Two or three left bones are included here.

TABLE I.

Bones of right side.	No.	Mean.	Stand-ard devia-tion.	Coeffi-cient of variation.	Pairs.						
					No.	Right.			Left.		
						Mean.	Stand-ard devia-tion.	Coeffi-cient of variation.	Mean.	Stand-ard devia-tion.	Coeffi-cient of variation.
Femur (maximum length), ♂	80	459·300	25·190	5·484							
" (length in oblique position), ♂	80	455·950	24·928	5·467	48	453·250	25·148	5·548	454·500	24·550	5·401
" (maximum length), ♀	113	426·270	20·748	4·867							
" (length in oblique position), ♀	113	422·146	20·825	4·933	66	421·409	19·449	4·615	422·864	20·608	4·873
Sexual ratio, $\frac{\text{♂}}{\text{♀}}$, femur (oblique)	..	*1·080*	..	*1·108*							
Tibia (maximum length), ♂	85	389·347	19·615	5·038							
" (excluding spine), ♂	85	379·700	18·769	4·943							
" (length from centre to centre of articular surfaces), ♂	85	365·170	17·898	4·901	57	365·815	18·348	5·016	366·553	19·102	5·211
" (maximum), ♀	115	358·256	17·658	4·929							
" (excluding spine), ♀	115	349·569	17·138	4·903							
" (from centre to centre), ♀	115	335·691	17·043	5·077	100	336·620	16·295	4·841	337·640	16·322	4·834
Sexual ratio, $\frac{\text{♂}}{\text{♀}}$, tibia (centre to centre)	..	*1·088*	..	*0·965*							
Fibula (maximum length), ♂	23	373·674	..	..	9	371·988	..	..	373·333	..	..
" (maximum), ♀	42	347·786	21·770	6·259	15	347·240	..	..	347·633	..	..
Sexual ratio, $\frac{\text{♂}}{\text{♀}}$	..	*1·074*		..							
Humerus (maximum), ♂	62	326·177	17·014	5·216							
" (length in oblique position) ♂	62	321·984	16·501	5·125	33	318·227	14·685	4·615	314·682	14·640	4·652
" (maximum), ♀	97	298·655	14·952	5·006							
" (oblique), ♀	97	295·974	14·768	4·990	52	294·885	14·215	4·821	288·846	14·245	4·932
Sexual ratio, $\frac{\text{♂}}{\text{♀}}$, humerus (oblique)	..	*1·088*	..	*1·027*							

TABLE I. (continued).

Bones of right side.	No.	Mean.	Standard deviation.	Coefficient of variation.	Pairs.						
					No.	Right.			Left.		
						Mean.	Standard deviation.	Coefficient of variation.	Mean.	Standard deviation.	Coefficient of variation.
Radius (maximum), ♂	47	256·968	12·901	5·021							
„ (centre to centre), ♂	47	243·351	12·618	5·185	21	245·785	11·957	4·865	243·738	11·135	4·568
„ (maximum), ♀	66	233·288	10·690	4·583							
„ (centre to centre), ♀	66	221·166	10·653	4·817	27	219·907	9·673	4·398	216·833	9·933	4·581
Sexual ratio, $\frac{♂}{♀}$, radius (centre to centre)	..	*1·100*	..	*1·076*							
Left ulna (maximum), ♂	41	276·451	15·442	5·586							
„ (excluding styloid), ♂	41	270·573	15·056	5·564	21	277·243	..	..	275·286	..	..
„ (maximum), ♀	66	250·500	13·869	5·537							
„ (excluding styloid), ♀	66	245·712	14·396	5·859	28	247·611	..	..	245·261	..	..
Sexual ratio, $\frac{♂}{♀}$, ulna (2nd measure)	..	*1·101*	..	*0·950*							
Clavicle (maximum), ♂	34	151·853	10·621	6·995	9	152·266	..	..	153·900	..	..
„ „ ♀	55	136·854	9·208	6·728	17	135·918	..	..	137·323	..	..
Sexual ratio, $\frac{♂}{♀}$	..	*1·110*	..	*1·040*							
Mean of sexual ratios	..	*1·092*	..	*1·028*							

In the 4th column the constant known as the "Error of Mean Square" (AIRY), or the "Standard Deviation" (PEARSON), is given. This is expressed in millimetres, and was always determined from the second "moment-coefficient" of the trapezia-system and not from the loaded ordinates. It is an absolute measure of dispersion about the mean. A relative measure is $\frac{\text{Standard Deviation}}{\text{Mean}}$,* this is called the "coefficient of variation," and has recently been introduced by Professor PEARSON. These relative measures of variability are given in the 5th column of the table.

The probable error of a standard deviation (σ) is given by an approximate formula $0{\cdot}6745 \frac{\sigma}{\sqrt{2n}}$, and of a coefficient of variation (v) by $0{\cdot}6745 \frac{v}{\sqrt{2n}}$, where $n =$ the number of observations. A general idea of the values of the probable errors may be obtained by inspection, as in the case of the means.

We can now see that the absolute measure of variation, as given by the standard deviation, is always greater in the longer bones than in the shorter, and in the male than in the female. There is no obvious reason why this should be the case; although, for instance, the tibia is a somewhat shorter bone than the femur, yet the absolute variation in magnitude is not necessarily smaller in the former than in the latter. Similarly, although the mean length of the bones of the female is shorter than that of the male, it does not follow that the standard deviation should be less. And does a percentage measure always express the variability of an organ as it affects an individual organism? Take, for example, the two femora of a man, if one is a quarter of an inch longer than the other, the percentage variation does not concern him, it is the absolute variation of a quarter of an inch that is of importance. It thus appears that a ratio-measure of variation does not always express the variability of a dimension as it affects the individual.

With this reservation we will examine the 4th and 5th columns of the table.

It will be seen that the *absolute variation* of the bones diminishes as we pass from the femur to the clavicle, that is as the dimension becomes smaller. Or, in other words, the absolute variation is roughly proportional to the absolute length. Also it can be observed that the female is considerably less variable than the male.

The *ratio-measure* of variation, on the other hand, indicates that the femur, tibia, humerus, and radius are all about equally variable, while the tibia, ulna, and clavicle appear to exhibit little, if any difference in this respect between the sexes.

These results would seem to show that the variability of the two sexes, relative to each other, is far from constant in different races. In the comparative table given above, we see that in the French the female is more variable than the male in the tibia, humerus, and radius, while in the New Race there is a distinct reverse tendency.

The present results would appear to confirm Professor PEARSON's generalisation that "the more primitive and savage a race the less will be the variation of both sexes, and the greater will be the approach to equality of variation between the sexes."*

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* This ratio is more conveniently expressed as a percentage.

It will now be best to deal with each bone separately.

THE FEMUR

In the very great majority of the femora the linea aspera was strongly marked, indicating great use of the muscles of the posterior part of the thigh. Frequently also the gluteal ridge was very prominent and rugged. The form of femur known as "femur à pilastre" occurred with considerable frequency. Here the linea aspera projects as a strong ridge or column. Two fairly distinct types were noticed: in the one (*F.l.* 235 in Plate) a cross section through the middle of the shaft would roughly resemble an isosceles triangle with the two sides slightly concave and the base convex; in the other, which is the commoner form (*F.r.* 175), the upper part of the triangle would appear to be replaced by a rectangle and the base would be somewhat more convex. In the latter type the flat top to the rectangular prism is much roughened, while in the former this is replaced by a moderately smooth edge.

It is much to be hoped that on some future occasion the transverse and antero-posterior diameters may be measured on all the femora, and then an accurate determination of this character could be made. At present it is only possible to state that the male series exhibited this form of femur more frequently than the female. As many as 8 per cent. of the male femora, but only 3 per cent. of the female possessed a strongly-marked column, while in 13 per cent. of the men and in 7 per cent. of the women this character was exhibited in a less pronounced form. To give some idea of these groups I measured five femora, and the "*pilastric indices*"† were 128, 124, 123 belonging to the first group, and 119 and 117 to the second group. The diameters were taken at the middle of the shaft.

Sir WILLIAM TURNER, in describing the bones collected by the *Challenger* Expedition, remarked that some of the femora, especially those from New Zealand, exhibited an antero-posterior compression at the upper end of the shaft. This condition has been termed "platymery" by M. MANOUVRIER, and he has instituted a *platyemric index,* which resembles the pilastric index, only that the diameters are taken at the sub-trochanteric section instead of at the middle of the shaft.

I have found that this platymeric condition was conspicuously exhibited in the few femora which had a very low pilastric index, while on the other hand the femora which possessed high pilastric indices seldom showed a trace of flattening at the upper end of the bone. This observation confirms **MANOUVRIER'S** statement that pilastric femora seldom exhibit platymery to any marked degree. Dr. **HEPBURN**[*] has recently determined the platymeric and pilastric indices on the femora of a considerable number of races, and his results agree in the main with this view, namely, that femora with high pilastric indices exhibit, as a rule, but little platymery,[†] while those with low pilastric indices are frequently platymeric to a greater or less degree.

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* "The Chance of Death and other Studies in Evolution," vol. 1, p. 303. This volume is about to be published.

† Pilastric index $= \frac{\text{Antero-posterior diameter}}{\text{Transverse diameter}} \times 100.$

In a few of the femora the antero-posterior diameter at the middle of the shaft was considerably less than the transverse, and so the index was below 100. The indices in two cases were: pilastric index, 89·8; platymeric index, 62·6 (see Plate *F.r.* 7)[‡]; and 96·3 and 76·4 respectively.

The Length-measurements of the Femur.

Table II. records the measurements made on the right femur in the oblique position. In the first and second divisions, headed male and female respectively, the measurements are absolute and are expressed in millimetres. In the third division the sexes are mixed, but the length of the femur is given in terms of the length of the tibia (measurement "*b*" where spine is excluded). When only one tibia was found in the skeleton it was taken as the standard, whether it was a right or left bone; if both tibiæ were present, the mean of the two was taken.

At the bottom of the table are given the various constants to the curves, which were calculated by the method of moments introduced by Professor **PEARSON**.[§] All these constants are expressed in terms of the units which are to be found at the tops of the 1st, 4th and 7th columns respectively.

$$\text{The centroid} = \text{position of arithmetic mean.}$$

$$\mu_2 = \text{the second ``moment coefficient.''}$$

$$= \frac{\text{the 2nd moment about the centroid}}{\text{No. of observations}}.$$

$$\sigma = \sqrt{\mu_2} = \text{Standard Deviation (PEARSON).}$$

$$= \text{Error of Mean Square (AIRY).}$$

$$\mu_3 = \text{the third ``moment coefficient.''}$$

$$\mu_4 = \text{the fourth ``moment coefficient.''}$$

$$\beta_1 = \mu_3^2/\mu_2^3, \text{ and } \beta_2 = \mu_4/\mu_2^2.$$

The critical function $= 2\beta_2 - 3\beta_1 - 6$. When this expression is positive the theoretical curve has an unlimited range, but when negative the range is limited.

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[*] 'Journal of Anatomy,' vol. 31, 1896.

[†] The Maoris would seem to form an exception.

[‡] In this femur there was a third trochanter; its position is indicated in the diagram by the sign (*) placed against the protuberance at the lower corner.

[§] 'Phil. Trans.,' A, vol. 186, 1895, pp. 343–414.

TABLE II.

R. femur in oblique position.						R. femur expressed in thousandths of tibia (malleolus included).		
Male series.			Female series.			Sexes mixed.		
Units = 6 millims.	Absolute measures in millims.	Frequency.	Units = 6 millims.	Absolute measures in millims.	Frequency.	Units = 0·008 of tibia length.	Thousandths of tibia length.	Frequency.
1	405–410	1	1	376–381	2	1	1142–1149	1
2	411–416	3	2	382–387	3	2	1150–1157	6
3	417–422	1	3	388–393	5	3	1158–1165	6
4	423–428	5	4	394–399	7	4	1166–1173	10
5	429–434	7	5	400–405	10	5	1174–1181	15
6	435–440	7	6	406–411	12	6	1182–1189	21
7	441–446	7	7	412–417	8	7	1190–1197	19
8	447–452	4	8	418–423	8	8	1198–1205	17
9	453–458	11	9	424–429	12	9	1206–1213	13
10	459–464	8	10	430–435	16	10	1214–1221	23
11	465–470	4	11	436–441	11	11	1222–1229	16
12	471–476	7	12	442–447	8	12	1230–1237	12
13	477–482	2	13	448–453	5	13	1238–1245	10
14	483–488	5	14	454–459	2	14	1246–1253	7
15	489–494	3	15	460–465	2	15	1254–1261	1
16	495–500	3	16	466–471	1	16	1262–1269	3
17	501–506	0	17	472–477	0	17	1270–1277	1
18	507–512	0	18	478–483	1	18	1278–1285	1
19	513–518	0				19	1286–1293	0
20	519–524	1				20	1294–1301	1
21	525–530	0						
22	531–536	1						
No. of observations .		80	No. of observations .		113	No. of observations .		183
Centroid = 9·0750. $\mu_2 = 17·2610$. $\sigma = 4·1546$. $\mu_3 = 35·0033$. $\mu_4 = 965·6331$. $\beta_1 = 0·2382$. $\beta_2 = 3·2400$. Critical function = $-$ 0·235.			Centroid = 8·2743. $\mu_2 = 12·0471$. $\sigma = 3·4709$. $\mu_3 = 2·7945$. $\mu_4 = 379·0705$. $\beta_1 = 0·0045$. $\beta_2 = 2·6119$. Critical function = $-$ 0·790.			Centroid = 8·4918. $\mu_2 = 12·6133$. $\sigma = 3·5515$. $\mu_3 = 13·6154$. $\mu_4 = 452·8204$. $\beta_1 = 0·0924$. $\beta_2 = 2·8462$. Critical function = $-$ 0·585.		

On account of the comparative fewness of observations the values of the constants coming after σ must be regarded as only very roughly giving some kind of approximation to true values. Still, it may be observed, that in the case of the femur all three critical functions are negative, and it will be found with the other bones that a negative value occurs more frequently than a positive one. From this it would seem that the curves resulting from the measurements of bones belong to that skew type which has a strictly limited range. How far such a theoretical range has any practical significance remains to be demonstrated, but it would require a much larger series than we have here before the theory could be satisfactorily applied to the length of bones. The range, given by the 113 female femora, has, however, been calculated; it is equal to 25·28 units, while the observed range is 18 units.

In the accompanying diagram, the frequency polygons are drawn. They all exhibit a marked double-humped character.* The number of observations is too small for us to feel any certainty as to the meaning of this. Perhaps it is a mere accident, or it may indicate that we have here two races, or a slight admixture of the sexes. If we compare these polygons with those given by the tibiæ, we shall see that the latter exhibit the double peak less strongly than do the former, while in the case of the humerus and of the radius, this character seems to have nearly disappeared. This favours the view that the double peak is merely accidental. It must be observed, however, that in two closely allied races, the femora might differ in length more perceptibly than the other bones, and so such a comparison is scarcely conclusive as to the homogeneous nature of the material. It may be remarked here, that most of the curves exhibit a distinct tailing off on the positive side of the centroid, the slope of the curve being steeper on the negative side. We have above seen that the polygons show a marked tendency to conform to skew curves of limited range, and we may conclude that this range is greater on the positive than on the negative side of the mean, or, in other words, that there is greater abnormality among long than among short bones.

On referring to Table I., it will be seen that the word "pairs" is placed at the head of the right half division. By a "pair" we mean the right and left bones of the same skeleton. In 47 pairs of male femora, the mean of the right bones was 1·11 millims. lower than the mean of the left, and in 66 female femora it was 1·55 millims. lower. The relation which was observed between the two sides is shown in the following scheme :—

Bone.	Sex.	No. of pairs.	Difference between the means of the R. and L. bones.†	No. of pairs with the R. and L. bones differing from one another by less than 1 millim.	Per-centage.	No. of pairs with the R. bones greater than the L.	Per-centage.	Average pre-ponderance of R. over L.	No. of pairs with the L. bones greater than the R.	Per-centage.	Average pre-ponderance of L. over R.
			millims.		per cent.		per cent.	millims.		per cent.	millims.
Femur . (Oblique)	♂	47‡	−1·11	10	21·3	17§	36·2	2·52	28§	59·6	3·40
	♀	66	−1·55	12	18·1	18	27·3	2·74	46	69·7	3·30

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* The ratio-curve, we should expect, would give some signs of its compound nature, for the femur, in proportion to the tibia, is slightly shorter in man than in woman, as we shall see later on.

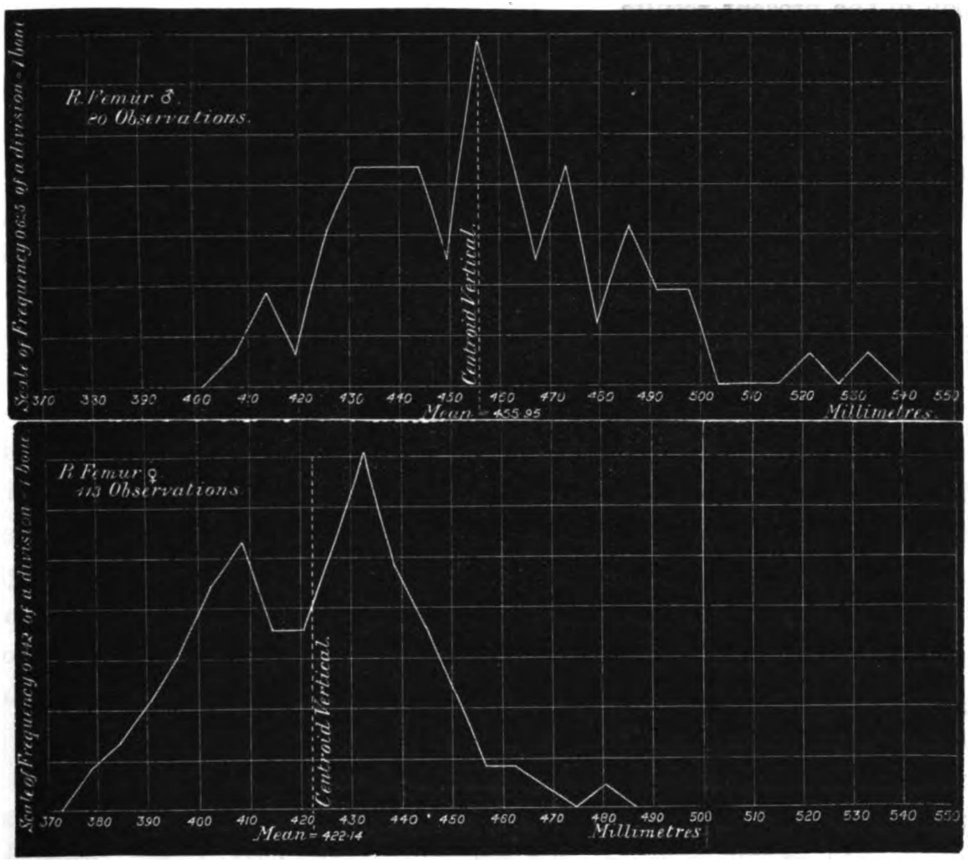
† These means were found by direct addition and division, and not from the centroid of the polygon in which the measurements were grouped. With such a few observations, a slight difference would be expected to occur.

‡ I have omitted a doubtful pair here, No. 874. It was included in Table I.

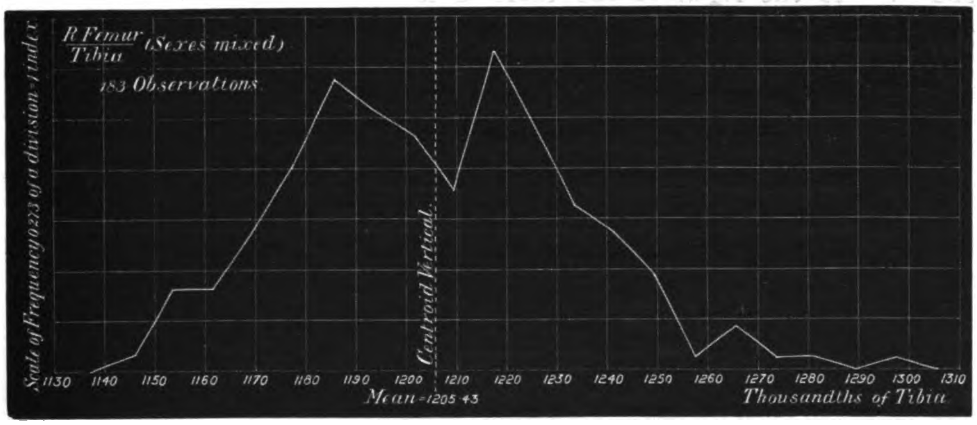
§ These numbers were obtained by using all the bones, whether they differed from one another by less than 1 millim. or not.

These results are similar to those obtained by Dr. J. G. Garson,* who some years ago investigated the subject of "side" on a series of 70 femora and tibiæ belonging to different races and to both sexes. Out of his 70 pairs of femora, the right and left bones differed from one another by less than 1 millim. in 9 cases (12·8 per cent.), while in 20 cases (28·6 per cent.) the right was greater than the left, and in 41 cases

Diagram I.



The above curves are reduced to the same area by adjusting the vertical scale.



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* 'Journal of Anatomy,' vol. 13, 1879.

(58·5 per cent.) the left was greater than the right. It was also noticed, that when the right bone was greater than the left, the difference between them (average preponderance = 2·9 millims.) was as a rule somewhat less than when the left was greater than the right (average preponderance = 3·8 millims.). A similar tendency can be seen in the present results.

An examination of the above table would appear to show that the difference between the means of the two sides was rather greater in woman than in man, and from this we should anticipate that there would be fewer cases in which the left bone was shorter than the right, and such we find actually occurs.

The standard deviations and the coefficients of variation appear to indicate no constant difference between the variability of the bones of the right and left side.

The Length of the "Neck + Head" of the Femur.

This dimension was measured from the point O (see Plate 22, fig. 1) to the point where the axis of the neck intersects the surface of the head. The latter point was always situated a short distance above the fossa for the interarticular ligament.

The measurements were expressed in terms of the maximum length of the femur (AB), and also in terms of the length of the shaft (OD). The results are given in Table III. The constants thus found show that the length of the neck + head in proportion to the length of the femur is greater in the male than in the female; also, according to both absolute and ratio-measures of variability, man would appear to be more variable than woman in this respect.

To ascertain the relationship between this length and the effective length of the femur (oblique length), a correlation was instituted between the two dimensions. Table IV. gives the means and variation constants of the pair of dimensions for each sex. The "*r*" to the right of the table is the "coefficient of correlation." This fraction expresses the relationship between the parts such that

If X = the average deviation of neck + head associated with a known mean deviation of a group of femora;
A = this known mean deviation of the femora;
Q_N = an absolute measure of the variability of neck + head;
Q_F = the similar measure of variation of the femur;

then

$$\frac{X/Q_N}{A/Q_F} = r. \quad \text{Therefore } X = (rQ_N/Q_F)\,A.$$

rQ_N/Q_F is called the "Coefficient of Regression."

These coefficients of correlation (otherwise known as GALTON'S Functions) were determined by means of the formula used by Professor PEARSON,*

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* 'Phil. Trans.,' A, vol. 187, 1896, pp. 253-318.

$$r = \frac{\Sigma \text{ deviation of A from its mean} \times \text{deviation of B from its mean}}{n\sigma_A\sigma_B},$$

where n = number of observations, and $\sigma_A\sigma_B$ are the standard deviations of the dimensions A and B respectively.

The probable errors of the coefficients were calculated from the formula,

$$0\cdot6745 \frac{1 - r^2}{\sqrt{r\,(1 + r^2)}}.$$

TABLE III.

$$\frac{\text{Neck + head of femur}}{\text{Maximum length of femur}}.$$

Male series.			Female series.		
Unit = 0·004 of the length of the femur.	Thousandths of femur.	Frequency.	Unit = 0·004 of the length of the femur.	Thousandths of femur.	Frequency.
1	135–138	1	1	129–132	1
2	139–142	0	2	133–136	0
3	143–146	3	3	137–140	2
4	147–150	4	4	141–144	2
5	151–154	3	5	145–148	12
6	155–158	10	6	149–152	17
7	159–162	11	7	153–156	25
8	163–166	6	8	157–160	12
9	167–170	4	9	161–164	11
10	171–174	1	10	165–168	4
11	175–178	2	11	169–172	0
			12	173–176	1
No. of individuals . .		45	No. of individuals . .		87
Mean . . . . = 158·6333 Standard deviation . . = 8·4894 Coefficient of variation . = 5·352			Mean . . . . = 154·0402 Standard deviation . . = 7·1932 Coefficient of variation . = 4·670		

$$\frac{\text{Neck + head of femur}}{\text{Length of shaft}}.$$

Male series.			Female series.		
Mean.	σ.	ν.	Mean.	σ.	ν.
183·855	10·585	5·757	179·029	9·023	5·043

TABLE IV.

Correlation between neck + head of femur and the oblique length of femur.

Sex.	No. of individuals.	Dimension.	Mean.	σ.	ν.	Dimension.	Mean.	σ.	ν.	r.	Probable error of r.
♂	43	Neck + head	71·604	4·940	6·899	Femur	448·395	18·952	4·227	0·6939	0·0438
♀	61	Neck + head	65·131	4·503	6·914	Femur	420·049	19·637	4·675	0·6772	0·0387

The coefficients of correlation which have been obtained for the above-mentioned pair of dimensions are fairly high, showing that the length of the neck + head varies simultaneously and more or less proportionally to the variations in the oblique length of the femur.

Other things being equal, an increase in the length of neck + head must necessarily increase the oblique length of the femur, and so from the nature of the case a certain amount of correlation must occur. But since the probable error of this dimension is very small in comparison with that of the whole length of the femur, this incidental correlation cannot be large. It may be stated, then, that most of the correlation which has been detected is due to the relation which exists between the variation in the length of the neck + head and that of the shaft of the femur. What was required to be known in the present case was how the deviations in the length of the neck + head are associated with deviations in the effective length of the femur, and under this aspect of the problem the different causes producing the correlation do not concern us.

Man is perhaps slightly more correlated in this respect than woman, but since the probable errors of the coefficients are so considerable, we can feel no confidence in the difference which is shown.

The Angle of the Neck with the Shaft.

This angle was measured by the method previously described; the results are summed up in the left half of Table V.

The mean angle is 2°·56 higher in the female than in the male; also the constants of variation appear to be greater in the former than in the latter.

Table VI. gives the coefficients of correlation between the angle of neck and the proportional length of head + neck to maximum length of femur. We see that the correlation is negative, indicating that a femur having a proportionally short neck and head will, as a rule, possess a somewhat high angle.

TABLE V.

The angle which the neck of the femur makes with the shaft.						The angle which the neck makes with the horizon when the femur is placed horizontally with its condyles on a flat surface.					
Male series.			Female series.			Male series.			Female series.		
Unit = 2°.	Angle.	Frequency.	Unit = 2°.	Angle.	Frequency.	Unit = 2°.	Angle.	Frequency.	Unit = 2°.	Angle.	Frequency.
1	111°–112°	2	1	98°–99°	1	1	2°–3°	1	1	9°–10°	2
2	113–114	0	. . . .	. . . . .	. . .	2	4–5	0	2	11–12	1
3	115–116	1	8	112–113	1	3	6–7	1	3	13–14	3
4	117–118	4	9	114–115	0	4	8–9	1	4	15–16	3
5	119–120	2	10	116–117	2	5	10–11	1	5	17–18	6
6	121–122	6	11	118–119	1	6	12–13	2	6	19–20	8
7	123–124	7	12	120–121	6	7	14–15	1	7	21–22	5
8	125–126	7	13	122–123	8	8	16–17	2	8	23–24	3
9	127–128	9	14	124–125	13	9	18–19	2	9	25–26	7
10	129–130	4	15	126–127	21	10	20–21	3	10	27–28	10
11	131–132	2	16	128–129	12	11	22–23	5	11	29–30	7
12	133–134	0	17	130–131	9	12	24–25	3	12	31–32	8
13	135–136	0	18	132–133	4	13	26–27	2	13	33–34	6
14	137–138	0	19	134–135	2	14	28–29	4	14	35–36	4
15	139–140	0	20	136–137	5	15	30–31	2	15	37–38	2
16	141–142	0	21	138–139	1	16	32–33	2	16	39–40	3
17	143–144	1	22	140–141	1	. . . .	. . . . .	. . .	17	41–42	2
			23	142–143	1	19	38–39	1			
No. of observations . .		45	No. of observations . .		88	No. of observations . .		33	No. of observations . .		80
Mean = 124°·255. Standard deviation = 5°·578. Coefficient of variation = 4·469.			Mean = 126°·818. Standard deviation = 6°·077. Coefficient of variation = 4·792.			Mean = 21°·712. Standard deviation = 8°·071. Coefficient of variation = 37·12.			Mean = 26°·100. Standard deviation = 7°·779. Coefficient of variation = 29·80.		

TABLE VI.

Sex.	No.	Dimension.	Dimension.	r.	Probable error of r.
♂	45	Angle of neck	$\frac{\text{Neck + head}}{\text{Femur (maximum)}}$	– 0·345	0·084
♀	88	,,	,,	– 0·273	0·064

Professor HUMPHRY* has stated that this angle "is smaller in short bones than in long bones," and "in women than in men." My measurements do not seem to confirm this conclusion, and it is not clear how the method of measurement would account for the disagreement. We have previously seen that women possess a short neck + head in proportion to the maximum length of the femur, and we now see that in both sexes such a condition tends to be associated with a high angle. In conformity with this, the mean angle in woman might be expected to be slightly higher than in man, and this is what we find in the present measurements. Dr. JOHANN MIKULICZ† has measured the angle of the neck on 100 femora from the Vienna hospitals. He gives the mean angle as lying between 125° and 126°, but the sexes are mixed. This is practically identical with the mean of Table V. The table which MIKULICZ publishes shows very little correlation between the length of the inferior extremity and the angle of the neck, and in the case of the New Race the correlation is very slight, but apparently positive. With regard to sex differences, nothing that is really satisfactory can be deduced from his measurements. I do not think from the data which are at present available that it can be safely concluded that this angle in Europeans is as a rule smaller in women than in men.

The Angle of Torsion.

The method of measurement has already been described. The true angle of torsion is given by the angle which the axis of the neck makes with the transverse axis of the lower extremity of the bone. The angle which was measured is the angle that the axis of the neck makes with the vertical plane touching the posterior surfaces of the condyles when the bone is held upright. This plane, however, is nearly parallel to the transverse axis.

The measurements are given in the right-hand division of Table V. The mean of the female series is 4°·39 higher than that of the male. MIKULICZ has measured the angle of torsion in 120 European femora; although his method of measurement differs from mine, yet our results are comparable. The mean angle of his series is 12°. In 10 cases the angle of MIKULICZ's series was negative, that is, the neck turned posteriorly instead of anteriorly. In my series only one negative angle was found, and that was in a left femur; the measurements I have recorded are those of the right femur. The table which MIKULICZ gives shows a range from — 25° to + 37° (sexes mixed), while my series ranged in the male from + 2° to + 39°, and in the female from + 9° to + 42°. It will be seen from these figures that the torsion of the femur in Europeans is very considerably less than in the New Race. We may hence conclude that the torsion-angle in the femur differs very widely in different races.

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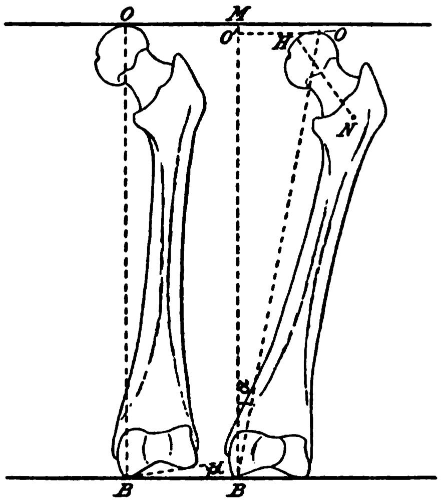
* 'Journal of Anatomy,' vol. 23, 1889.

† 'Archiv für Anatomie,' 1878.

The Relation between the Maximum and Oblique Lengths of the Femur.

The ratio of the maximum length (OB) to the oblique length (O′B) will give the secant to the angle (α) which the condyles make with the horizontal plane when the bone is held vertically in the "maximum position." This angle α is equal to the angle of deflection of the line OB from the vertical when the bone is placed in the "oblique position."



From Table VII. we see that the angle α is 1°·43 larger in the female than in the male. Now, there is apparently no correlation between this angle and the length of the femur (see Table VIII.); consequently it would seem that, other things being equal, the size of the angle depends upon the width of the pelvis. We have previously seen that long femora tend to have a proportionally long neck and head (NH), hence, in tall persons this angle is not necessarily altered, since the shaft of the bone is thrown a little further outwards by the increase in the dimension HN.

From these considerations it appears highly probable that a fairly strong correlation would be found to exist between this angle α and a suitable breadth-measurement of the pelvis, such as the distance between the centres of the acetabula.

The coefficients thus obtained might be of very great service in determining the breadth of the pelvis of prehistoric peoples by means of their femora.

TABLE VII.

The angle which the condyles of R. femur make with the horizontal plane when the bone is held upright in the "maximum position."					
Male series.			**Female series.**		
Unit = 1°.	Degrees.	**Frequency.**	**Unit = 1°.**	**Degrees.**	**Frequency.**
	°			°	
1	0	1	1	2	3
2	1	0	2	3	4
3	2	3	3	4	4
4	3	7	4	5	17
5	4	12	5	6	13
6	5	7	6	7	18
7	6	23	7	8	22
8	7	11	8	9	14
9	8	8	9	10	13
10	9	6	10	11	2
11	10	2	11	12	1
			12	13	1
			13	14	1
No. of individuals . .		80	**No. of individuals . .**		113
Mean . . . . = 5°·7875 Standard deviation . . = 2°·0637 Coefficient of variation . = 35·658			**Mean . . . . = 7°·2212 Standard deviation . . = 2°·3164 Coefficient of variation . = 32·078**		

TABLE VIII.

Correlation between angle of condyles and maximum length of R. femur.									
Sex.	No.	Bone.	Mean.	σ.	**Angle.**	**Mean.**	σ.	r.	**Probable error of r.**
						°	°		
♂	80	Femur	459·3125	25·2365	**Angle of condyles**	5·7875	2·0637	−0·0395	0·0752
♀	113	,,	426·3717	21·0211	,,	7·2212	2·3164	0·0192	0·0634

THE TIBIA.

In Table I. are given the means of the different measurements made on the tibia. With regard to the standard deviations it may be noticed that the maximum length is the most variable dimension in both the male and female, while the distance from centre to centre of articular surfaces would appear to be the least variable. Reference to the coefficients of variation shows us that the variability is roughly proportional to the length of the dimension; and this is what we found in the case of the different bones, namely, that the longer a bone the greater, as a general rule, is the absolute variation which it exhibits. We now find that the same law holds with respect to different parts of the same bone.

Among the tibiæ some typical examples of the condition known as platycnemia occurred (see Plate 22, *Tr. T.* 40 and *Tr.* 382). It was well marked in 8·5 per cent. of the male series and in 4·6 per cent. of the female, and so, like the pilastric femur, it is less frequent in woman than in man. To give some notion of these groups, I obtained four platycnemic indices;* they were 50, 52·7, 59, 64.

Although it is impossible by mere inspection to give a trustworthy account of this character, yet it may be stated that a platycnemic tibia was frequently associated with a more or less pilastric femur. Thus, in the same skeleton, there seems to be some correlation between the tibia and femur in this respect.

It would be very desirable if the pilastric and platycnemic indices were found for all the couples of these two bones, for then the coefficient of correlation between the two series of indices would accurately measure the relationship which exists between these two conditions in the same skeleton.

Many of the tibiæ, and especially the platycnêmic ones, exhibited a very marked curvature of the upper end, such that, when the shaft of the bone was held vertically, the upper part was obviously bent posteriorly.

M. **Paul Broca** originally considered that platycnemia was a sign of degeneration, but he held that the possession of a pilastric femur was a character of superiority. Professor **Manouvrier**† has since pointed out that there are certain differences between the platycnemia in man and that in the anthropoid apes, as exhibited in the gorilla. Platycnemia is due to the antero-posterior expansion of the bone, especially behind the interosseous ridge, and concurrently the posterior surface may disappear. Over the expansion spreads the attachment of the tibialis posticus muscle. In some of the tibiæ of the New Race the surface of attachment of the tibialis anticus was very markedly hollowed out. In the platycnemia of the gorilla both the tibialis posticus and the flexor longus digitorum are inserted on the outer side of the expansion; while in the platycnemia of man the latter muscle comes to be inserted on the inner surface, being pushed round, so to speak, by the great extension of the area of attachment of the tibialis posticus. (See Plate 22, fig. *T. r.*, *T.* 40.)

A careful examination of the tibiæ of the New Race confirmed this view, and the connection between the antero-posterior extension of the tibia and that of the femur in the same skeleton would seem to demonstrate that both characters are due to similar causes, and that the platycnemia, as ordinarily exhibited in man, is not a reversion to a simian character, for the pilastric femur is essentially human.

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* Platycnemic index $= \dfrac{\text{Trans diameter}}{\text{Antero-posterior diameter}} \times 100$ measured at the level of the nutritive foramen.

† 'Mém. de la Soc. d'Anthropologie de Paris,' vol. 3, 1888.

Here, then, we appear to have a character which is produced by the direct action of use, and probably any hardy race of hunters would exhibit the flattening to a greater or less degree. A tibia assumes its platycnemic form only after puberty, and it would be exceedingly interesting to know whether this character, which seems to be purely "acquired," could be inherited.

Some years ago, Mr. ARTHUR THOMSON* drew attention to the fact that in many savage races a facet could be found upon the anterior margin of the articular surface of the tibia with the astragalus. He also noticed that, in the tibiæ exhibiting these facets, the external condyloid surface was frequently flattened, or even convex. These characters he attributed to a frequently-assumed squatting posture. In the majority of the tibiæ of the New Race this facet could be detected, also, in the same bones the outer condyloid surfaces were often convex, instead of being slightly concave. We may hence conclude that "squatting" was the habitual custom of the New Race.

As it has been above remarked, many of the tibiæ exhibited a strong backward curvature of the upper extremity. Professor MANOUVRIER has pointed out that such a curvature would serve to increase the resistance to an anterior sliding of the condyles of the femur in flexion of the leg. MANOUVRIER is inclined to attribute this curvature to the same causes as those producing platycnemia, and my observations are in accordance with his view, in that the platycnemic tibiæ were generally greatly bent. I could trace no connection between this bending and the presence of facets or of the convexity of the outer condyloid surface, for sometimes there was a strong curvature, but no facets could be distinguished, while on the other hand, nearly straight tibiæ often exhibited both facets and convexity of the surface.

The Length-Measurements of the Tibia.

The measurements which were made on the right tibiæ are recorded in Table IX. In the division to the right the sexes are mixed, but the measurements are expressed in terms of the maximum length of the femur.

The frequency polygons are shown in Diagram II. Considering the fewness of observations they are fairly regular.

The dispersion about the mean is clearly asymmetrical, and consequently nothing but some form of skew curve would fit our frequency curve. The critical function of the curve obtained from the absolute measures is negative in both sexes, and so a limited range is indicated In the case of the 115 female tibiæ, the theoretical range is 26·78 units, while the observed range is 15 units.

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* 'Journal of Anatomy,' vol. 23, 1839.

TABLE IX.

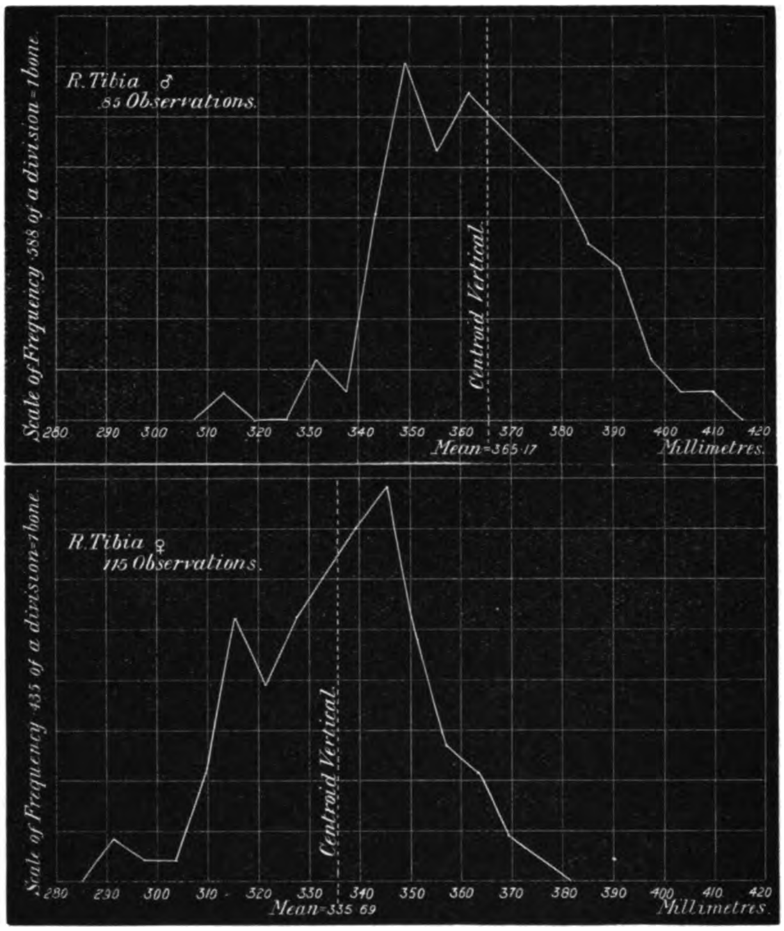
R. tibia measured from centre to centre of articular surfaces.						R. tibia expressed in thousandths of femur (maximum length).		
Male series.			Female series.			Sexes mixed.		
Units = 6 millims.	Absolute measures in millims.	Frequency.	Units = 6 millims.	Absolute measures in millims.	Frequency.	Units = 0·0066 of the length of femur.	Thousandths of femur.	Frequency.
1	311–316	1	1	289–294	2	1	725·1–731·6	1
2	317–322	0	2	295–300	1	2	731·7–738·2	2
3	323–328	0	3	301–306	1	3	738·3–744·8	2
4	329–334	2	4	307–312	5	4	744·9–751·4	1
5	335–340	1	5	313–318	12	5	751·5–758·0	1
6	341–346	7	6	319–324	9	6	758·1–764·6	9
7	347–352	12	7	325–330	12	7	764·7–771·2	11
8	353–358	9	8	331–336	14	8	771·3–777·8	20
9	359–364	11	9	337–342	16	9	777·9–784·4	21
10	365–370	10	10	343–348	18	10	784·5–791·0	29
11	371–376	9	11	349–354	11	11	791·1–797·6	22
12	377–382	8	12	355–360	6	12	797·7–804·2	20
13	383–388	6	13	361–366	5	13	804·3–810·8	20
14	389–394	5	14	367–372	2	14	810·9–817·4	11
15	395–400	2	15	373–378	1	15	817·5–824·0	8
16	401–406	1				16	824·1–830·6	5
17	407–412	1				17	830·7–837·2	2
						18	837·3–843·8	1
						19	843·9–850·4	1
						20	850·5–857·0	1
No. of observations .		85	No. of observations .		115	No. of observations .		188
Centroid = 9·6118. $\mu_2 = 8·8983$. $\sigma = 2·9830$. $\mu_3 = 1·0871$. $\mu_4 = 232·5320$. $\beta_1 = 0·0017$. $\beta_2 = 2·9368$. Critical function = −0·141.			Centroid = 8·3652. $\mu_2 = 8·0681$. $\sigma = 2·8404$. $\mu_3 = -4·4798$. $\mu_4 = 181·9103$. $\beta_1 = 0·0382$. $\beta_2 = 2·794$. Critical function = − 0·525.			Centroid = 10·5160. $\mu_2 = 9·9696$. $\sigma = 3·1574$. $\mu_3 = 1·4866$. $\mu_4 = 352·1503$. $\beta_1 = 0·0223$. $\beta_2 = 3·5430$. Critical function = 1·019.		

The following observations have been made on the relative lengths of the right and left tibiæ of the same skeleton. In the male "pairs" the mean of the right bones was 0·77 millim. lower than the mean of the left, and in the female series it was 1·05 millim. lower :—

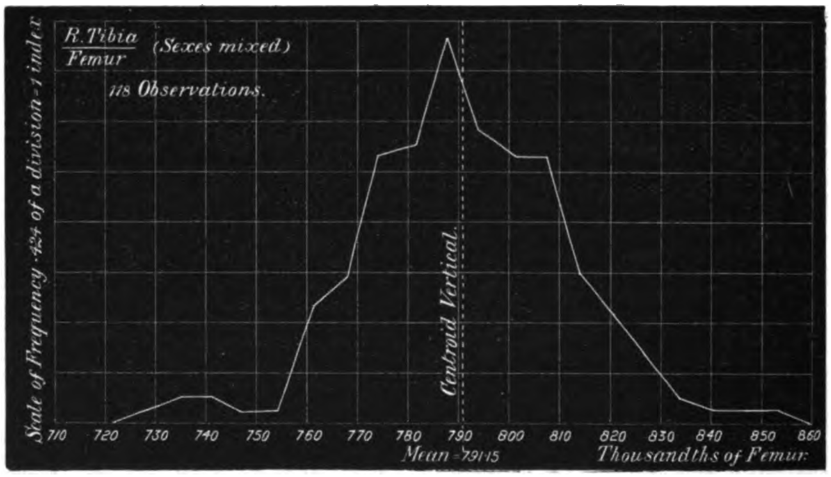
Bone.	Sex.	No. of pairs.	Difference between the means of the R. and L. bones.*	No. of pairs with the R. and L. bones differing from one another by less than 1 millim.	Percentage.	No. of pairs with the R. bones greater than the L.	Percentage.	Average preponderance of R. over L.	No. of pairs with the L. bones greater than the R.	Percentage.	Average preponderance of L. over R.
			millims.		per cent.		per cent.	millims.		per cent.	millims.
Tibia (centre to centre)	♂	57	−0·77	13	22·8	20	35·1	2·41	35	61·4	2·64
	♀	100	−1·05	25	25	35	35	1·52	62	62	2·56

* See the notes which are referred to in the similar table of the femur.

Diagram II.



The above curves are reduced to the same area by adjusting the vertical scale.



Here, as in the case of the femur when the right bone was longer than the left, the difference tends to be somewhat less than when the left was greater than the right. Also the difference between the means of the right and left bones was greater in woman than in man.

We have previously seen that the difference between the means of the right and left femur was — 1·11 millim. in the male and — 1·55 millim. in the female. Hence we find that in the New Race the mean excess of L. femur + L. tibia over R. femur + R. tibia was in the male about 1·88 millim., and in the female about 2·60 millims.

Dr. Garson stated that in his 70 skeletons the average preponderance of the left limb over the right was 1·5 millim. Also, from certain measurements given by Sir William Turner, it would seem probable that considerable differences exist among races as regards the mean length of the bones on the two sides of the body.

The Fibula.

The maximum length of the bone was taken. Among the fibulæ 3 per cent. were excessively flattened or channelled out laterally by deep longitudinal grooves, and 11·3 per cent. exhibited this character to a somewhat less degree. As we should have expected, the flattening of the fibula was related to the platycnemia of the tibia, so that a platycnemic tibia was frequently associated with a more or less channelled fibula.

Like the tibia, the left fibula is longer than the right.

The Humerus.

Both the maximum and the oblique lengths were measured on this bone. The means of the measurements are given in Table I.

Perforation of the septum between the coronoid and olecranon fossæ occurred with remarkable frequency. In some cases the septum had obviously been broken, occasionally it was not easy to be sure whether the perforation was real or had been accidentally produced. Whenever any doubt existed on this head the humerus was excluded from the following statistics :—

Sex.	No. of humeri of right side.	No. which were perforated.	Percentage.	No. of humeri of left side.	No. which were perforated.	Percentage.	Out of 126 pairs.		
							No. of pairs with both right and left bones perforated.	No. of pairs with R. bone perforated only.	No. of pairs with L. bone perforated only.
			per cent.			per cent.			
♂	80	17	21·2	82	28	34·1	..	..	..
♀	109	50	45·9	125	71	56·8	..	..	..
Sexes mixed	232	84	36·2	280	134	47·8	44 (=34·9°/o)	8 (=6·3°/o)	25 (=19·7°/o)

An examination of these figures will show that perforation occurs more frequently in the female than in the male, and on the left side than on the right.

From observations on the elbow-joint, it appeared to me that perforation is largely dependent upon the relative sizes of the olecranon and the olecranon fossa. When the parts were of such a size that on extension of the forearm the beak of the great sigmoid cavity came into contact with the septum, then that septum was generally perforated. The greater frequency of perforation in the female may, perhaps, be due to two causes; (1) the humerus is less robust, and, consequently, the septum is thinner and more readily perforated; (2) and possibly the olecranon is relatively somewhat smaller in woman than in man, for a very slight relative decrease in the size of the olecranon would have a great effect in bringing the beak into contact with the septum. I believe that the perforation occurring more frequently on the left side than on the right is due to this latter influence, for the left olecranon is probably somewhat shorter than the right, because the total length of the left ulna is very appreciably shorter, and it would seem feasible to suppose that the length of the olecranon would be proportional to the total length of the bone.

The strong anterior curvature of the proximal end of the ulna would also help to bring the beak of the olecranon against the septum, and this might perhaps partially account for the incurved ulna and perforated humerus occurring together in certain races.*

Dr. PAUL TOPINARD† has given the following statistics :—

	Perforated.
156 humeri from dolmens around Paris of the Polished Stone Period	21·8 per cent.
30 humeri of the Yellow Races of America	36·2 ,,
200 humeri of Parisians of 4th–12th century	5·5 ,,
218 humeri of Parisians of Middle Ages	4·1 ,,

In Negroes perforation occurs in about 21 per cent.‡

On comparing these percentages with those obtained from the New Race we see that the latter are very exceptionally high.

The Length-Measurements of the Humerus.

Some of the results of the different measurements are given in Table X. In the fourth division of the table the sexes are mixed, but the measurements are expressed in thousandths of the tibia. It may be noticed that the humerus in the oblique position seems to be slightly less variable than when the maximum length is taken (see Table I.). The distributions of deviations about the mean are exhibited to the eye in Diagram III.

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[*] How far such an explanation would apply to anthropoid apes I am not prepared to state. In a Chimpanzee skeleton I examined, both humeri were perforated, but the beak of the olecranon appeared quite incapable of touching the septum.

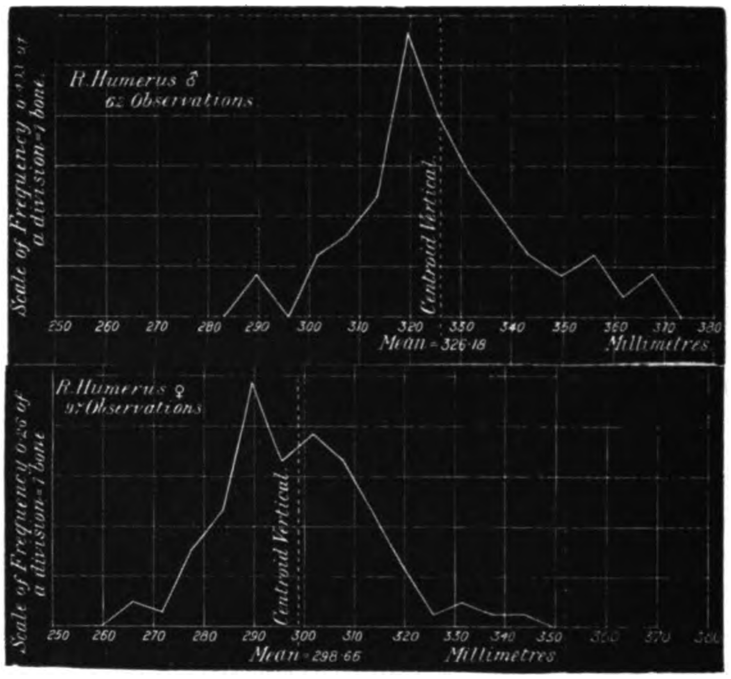
[†] 'Éléments d'Anthropologie Générale,' Paris, 1885.

[‡] See Sir WILLIAM TURNER's Memoir in the '*Challenger* Reports,' vol. 16.

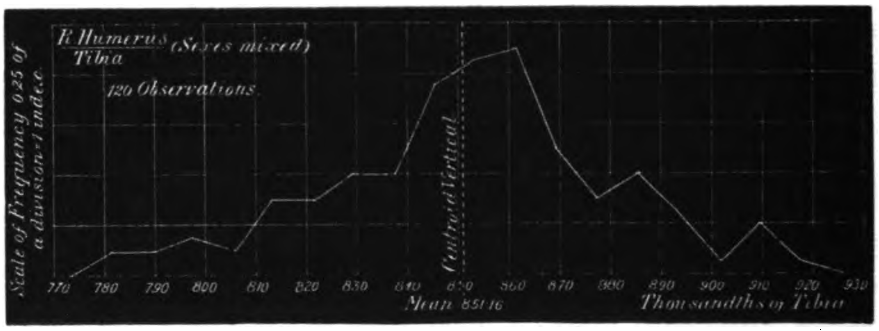
TABLE X.

R. humerus (maximum length).						R. humerus measured in the oblique position.			R. humerus (oblique) expressed in thousandths of tibia (including malleolus).		
Male series.			Female series.			Female series.			Sexes mixed.		
Units = 6 millims.	Absolute measures in millims.	Frequency.	Units = 6 millims.	Absolute measures in millims.	Frequency.	Units = 6 millims.	Absolute measures in millims.	Frequency.	Units = 0·008 of tibia length.	Thousandths of tibia.	Frequency.
1	287–292	2	1	263–268	2	1	261–266	2	1	778–785	2
2	293–298	0	2	269–274	1	2	267–272	2	2	786–793	2
3	299–304	3	3	275–280	6	3	273–278	4	3	794–801	3
4	305–310	4	4	281–286	9	4	279–284	12	4	802–809	2
5	311–316	6	5	287–292	19	5	285–290	17	5	810–817	6
6	317–322	14	6	293–298	13	6	291–296	15	6	818–825	6
7	323–328	10	7	299–304	15	7	297–302	16	7	826–833	8
8	329–334	7	8	305–310	13	8	303–308	13	8	834–841	8
9	335–340	5	9	311–316	9	9	309–314	7	9	842–849	15
10	341–346	3	10	317–322	5	10	315–320	4	10	850–857	17
11	347–352	2	11	323–328	1	11	321–326	1	11	858–865	18
12	353–358	3	12	329–334	2	12	327–332	2	12	866–873	10
13	359–364	1	13	335–340	1	13	333–338	1	13	874–881	6
14	365–370	2	14	341–346	1	14	339–344	1	14	882–889	8
									15	890–897	5
									16	898–905	1
									17	906–913	2
									18	914–921	1
No. of observations . .		62	No. of observations . .		97	No. of observations . .		97	No. of observations . .		120
Centroid = 7·1129. μ_2 = 8·0410. σ = 2·8357. μ_3 = 9·2508. μ_4 = 206·5318. β_1 = 0·1646. β_2 = 3·1942. Critical function = − 0·105.			Centroid = 6·5258. μ_2 = 6·2098. σ = 2·4919. μ_3 = 6·0649. μ_4 = 128·6261. β_1 = 0·1536. β_2 = 3·3356. Critical function = 0·210.			Centroid = 6·4124. μ_2 = 6·0585. σ = 2·4614. μ_3 = 6·8472. μ_4 = 131·1392. β_1 = 0·2108. β_2 = 3·5728. Critical function = 0·513.			Centroid = 9·7083. μ_2 = 12·0566. σ = 3·4723. μ_3 = − 10·9132. μ_4 = 436·6233. β_1 = 0·0680. β_2 = 3·0037. Critical function = − 0·197.		

Diagram III.



The above curves are reduced to the same area by adjusting the vertical scale.



In the scheme below are given the relations which were observed between the humeri of the right and left sides in "pairs" of bones.

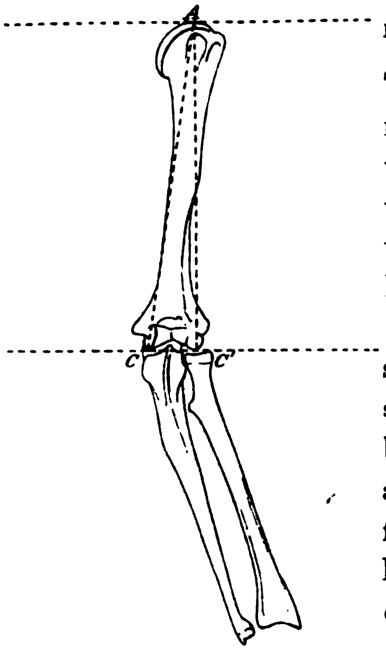
Bone.	Sex.	No. of pairs.	Difference between the means of the R. and L. bones.	No. of pairs with the R. and L. bones differing from one another by less than 1 millim.	Per-centage.	No. of pairs with the R. bones greater than the L.	Per-centage.	Average pre-ponderance of R over L.	No. of pairs with the L. bones greater than the R.	Per-centage.	Average pre-ponderance of L over R.
			millims.		per cent.		per cent.	millims.		per cent.	millims.
Humerus	♂	33	+3·38	4	12·1	27	81·8	4·52	6	18·2	1·75
(Oblique)	♀	52	+5·73	2	3·8	49	94·2	6·15	3	5·8	1·03

Here we notice, as in the femur and tibia, that the difference between the means of the right and left bones was greater in woman than in man.

The bones of the superior extremity were longer on the right side than on the left, while with those of the inferior extremity we have found that the left were longer than the right.

The Relation Between the Maximum and Oblique Lengths of the Humerus.

The oblique length of the humerus is analogous to that of the femur, and the relation between it and the maximum length may be expressed as before by determining the angle which has its secant $= \frac{\text{max. length}}{\text{oblique length}}$. This is the angle which the distal articular surfaces make with the horizontal plane when the bone is held upright in the maximum position, or very nearly equal to the inclination of the axis of the shaft to the vertical when the trochlea and capitellum are placed on a horizontal plane.



The vertical through the most prominent point of head is here made to fall on the capitellum. Frequently it falls outside of this.

The oblique length of the humerus does not represent so closely the effective length of the bone as does the similar measure in the femur, but it would seem to be a better measure of it than the maximum length. This appears to be proved by the following rather remarkable fact. On ascertaining the coefficients of correlation for the lengths of pairs of bones, it was found that all the bones except the radius were more closely correlated with the maximum length of the humerus (AC) than with its oblique length (AC′). The radius, on the other hand, in both sexes, would seem to be slightly more closely correlated with the oblique than with the maximum length.

Let us consider the articulations along CC′. If the inner margin of the trochlea,* C, be supposed to become a little more prominent, then the oblique length will be shorter. Other things being equal, the humerus will be thrown further outwards and the capitellum C′ will approach the head of the radius, which bone will consequently have to be somewhat shorter if there is to be free play for the supination of the hand.

In Table XI. are recorded the angles which were found for the male and female series. The mean of the male series is nearly a degree higher than that of the female, and considering the probable error of the mean, the difference would appear to indicate that this angle is slightly larger in man than in woman.

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* The degree of prominence of the inner edge of the trochlea is apparently much more variable than that of the globular capitellum.

TABLE XI.

R. Humerus. The angle which the distal articular surfaces make with horizontal plane when the bone is held upright in the maximum position.

Male series.			Female series.		
Unit = 1°.	Degrees.	Frequency.	Unit = 1°.	Degrees.	Frequency.
	°			°	
1	2	2	1	− 2	1
2	3	2	2	− 1	0
3	4	4	3	0	4
4	5	5	4	1	0
5	6	8	5	2	1
6	7	8	6	3	2
7	8	4	7	4	7
8	9	11	8	5	12
9	10	8	9	6	10
10	11	1	10	7	18
11	12	4	11	8	13
12	13	6	12	9	11
			13	10	10
			14	11	4
			15	12	2
			16	13	1
			17	14	0
			18	15	1
No. of Individuals . .		63	No. of individuals . .		97
Mean = 7°·9841. Standard deviation = 2°·9479. Coefficient of variation = 36·931.			Mean = 7°·0000. Standard deviation = 2°·9290. Coefficient of variation = 41·843.		

TABLE XII.

The angle of obliquity in "pairs" of humeri.

Side.	Male (33 pairs).			Female (51 pairs).		
	Mean.	σ.	ν.	Mean.	σ.	ν.
	°	°		°	°	
R. . . .	7·4545	2·9832	40·019	6·7451	2·7231	40·372
L. . . .	7·7879	2·6112	33·530	6·8039	2·8441	41·801

The angles for the right and left humeri of the same skeleton are generally similar to each other. There is no appreciable difference between the means of the two sides. Out of 33 male pairs, there were 5 pairs (15·1 per cent.) in which the angles differed from each other by less than a quarter of a degree. The mean of the differences between the right and left bones of the whole series was 1° 49′. Out of 51 female pairs, there were also 5 pairs (9·8 per cent.) with the angles differing from each other by less than the above amount, and the mean of the differences was 1° 43′.

There would appear to be only a very weak correlation between this angle of the humerus and the similar angle of the femur. (Table XIII.)

From the same table it will be seen that the angle tends to be larger in long than in short humeri.

TABLE XIII.

Pairs of dimensions.	Sex.	No.	r.	Probable error of r.
Angle of R. humerus and angle of R. femur	♀	51	0·0926	0·0829
Angle of R. humerus and maximum length of R. humerus	♀	97	0·2212	0·0636

THE RADIUS.

On these bones, two measurements were taken; the maximum length in the long axis of the bone, and the distance between the points where the longitudinal axis intersects the articular surfaces.[*] The details are given in Table XIV. The ratio curve obtained by expressing the radius in terms of the tibia is remarkably symmetrical for such a small number of observations. (Diagram IV.) The critical function of the curve is negative, and consequently we have a limited range; this was calculated, and it was found to be 14·91 units. The observed range was 11 units, and this is not far removed from the theoretical range.

Like the humerus, the radius of the right side was longer than that of the left. The following scheme gives the relations which were observed between the right and left bones of "pairs" of radii.

Bone.	Sex.	No. of pairs.	Difference between the means of the R. and L. bones.	No. of pairs with the R. and L. bones differing from one another by less than 1 millim.	Per-centage.	No. of pairs with the R. bones greater than the L.	Per-centage.	Average pre-ponderance of R. over L.	No. of pairs with the L. bones greater than the R.	Per-centage.	Average pre-ponderance of L. over R.
			millims.		per cent.		per cent.	millims.		per cent.	millims.
Radius[†] (c. to c.)	♂	21	+2·03	1	4·8	15	71·4	3·45	5	23·8	1·80
	♀	27	+3·05	6	22·2	23	85·1	3·65	3	11·1	0·53

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[*] I sometimes refer to this measure by the abbreviation (c. to c.), although the distal point is not quite the centre of the articular surface.

[†] See the notes referred to in the table of the femur.

TABLE XIV.

R. radius, measured from centre to centre of articular surfaces.						R. radius, measurements expressed in thousandths of tibia length.		
Male series.			Female series.			Sexes mixed.		
Units = 4 millims.	Absolute measures in millims.	Frequency.	Units = 4 millims.	Absolute measures in millims.	Frequency.	Units = 0·008 of tibia-length.	Thousandths of tibia.	Frequency.
1	209–212	1	1	203–206	4	1	594–601	1
2	213–216	0	2	207–210	7	2	602–609	3
3	217–220	0	3	211–214	8	3	610–617	4
4	221–224	1	4	215–218	8	4	618–625	14
5	225–228	2	5	219–222	10	5	626–633	14
6	229–232	4	6	223–226	15	6	634–641	17
7	233–236	4	7	227–230	4	7	642–649	14
8	237–240	8	8	231–234	2	8	650–657	14
9	241–244	9	9	235–238	3	9	658–665	7
10	245–248	5	10	239–242	1	10	666–673	6
11	249–252	3	11	243–246	2	11	674–681	3
12	253–256	4	12	247–250	2			
13	257–260	1						
14	261–264	2						
15	265–268	0						
16	269–272	2						
17	273–276	1						
No. of observations .		47	No. of observations .		66	No. of observations .		97
Centroid = 9·2128. μ_2 = 9·9512. σ = 3·1545. μ_3 = 9·4045. μ_4 = 348·3366. β_1 = 0·0897. β_2 = 3·5176. Critical function = 0·766.			Centroid = 5·1667. μ_2 = 7·0934. σ = 2·6633. μ_3 = 11·9714. μ_4 = 160·8118. β_1 = 0·4015. β_2 = 3·1960. Critical function = − 0·813.			Centroid = 6·3196. μ_2 = 5·0439. σ = 2·2454. μ_3 = 0·6830. μ_4 = 64·6901. β_1 = 0·0035. β_2 = 2·5427. Critical function = − 0·925.		

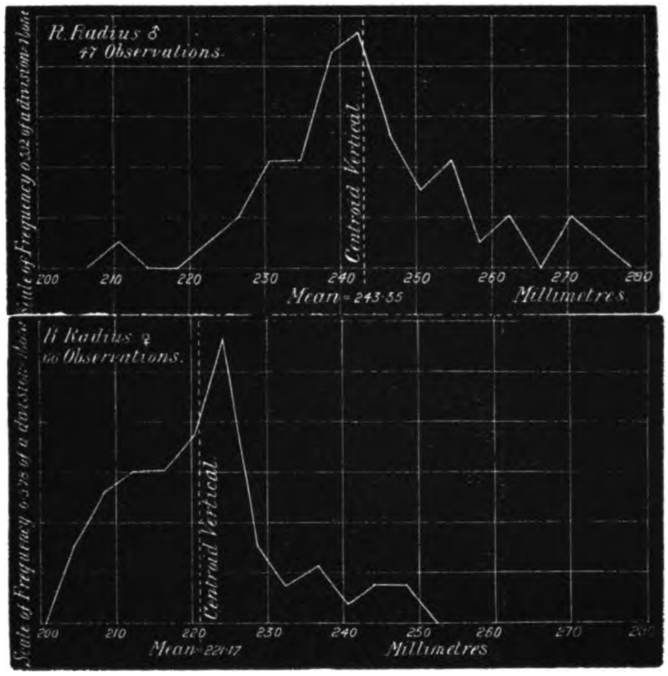
The constants of the L. radius (expressed in terms of tibia) are:—No. of observations 84, Observed range 589–684 thousandths, Centroid 5·3452, μ_2 = 6·1070, σ = 2·4712, μ_3 = − 1·5567, μ_4 = 89·4063, β_1 = 0·0106, β_2 = 2·3972, Critical function = − 1·2374. Theoretical range = 13·78.

As with all the other bones, greater asymmetry can be observed in woman than in man.

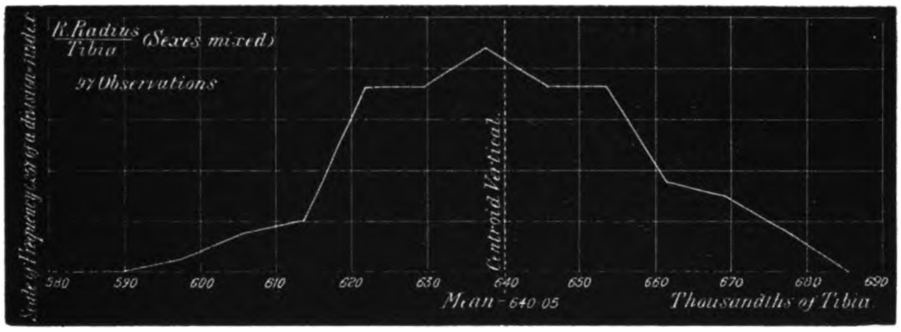
In the male the humerus + radius on the right side was, on the average, about 5·41 millims. longer than on the left, in the female it was about 8·78 millims. longer, and hence woman was approximately 3·37 millims. more asymmetrical than man.

In the case of the inferior extremity a similar though a less marked difference was found between the sexes; the female had a mean excess of about 0·72 millim. over the male asymmetry.

Diagram IV.



The above curves are reduced to the same area by adjusting the vertical scale.



THE ULNA.

The measurements made on this bone were: the maximum length in the direction of the long axis, and the distance from the centre of the inferior articular surface to the point where the longitudinal axis cuts the surface of the olecranon.

This bone was remarkable in several respects. The olecranon was very variable in size, occasionally it was large and massive, but more often it was small in proportion to the length of the bone, and sometimes it was diminutive to an exceptional degree. The upper third of the bone in the majority of cases exhibited an anterior curvature. This curvature was strongly marked in 21·7 per cent. (see U. *r.* B. 114 in Plate 22). I noticed a tendency for a much curved ulna to occur with a platycnemic tibia and a pilastric femur.

It would seem then that, under certain circumstances, the limb-bones are so acted upon by a vigorous musculature that they assume these special forms.

The measurements are recorded in Table XV., the left ulna is given because it happened to constitute the larger series. There is a certain resemblance between these curves and those of the radius, and this is especially the case with the ratio-curve where the length of the ulna is expressed in terms of the length of the tibia. In this curve the critical function is negative and the theoretical range is 18·29 units, and this is not very different from the observed range (13 units). A similar result was obtained for the radius.

TABLE XV.

L. ulna. The styloid process is excluded.						R. ulna. The measurements are expressed in thousandths of tibia length.		
Male series.			Female series.			Sexes mixed.		
Units = 4 millims.	Absolute measures in millims.	Frequency.	Units = 4 millims.	Absolute measures in millims.	Frequency.	Units = 0·008 of tibia-length.	Thousandths of tibia.	Frequency.
1	228–231	1	1	199–202	1	1	668–675	1
2	232–235	0	2	203–206	0	2	676–683	2
3	236–239	1	3	207–210	0	3	684–691	7
4	240–243	0	4	211–214	0	4	692–699	4
5	244–247	0	5	215–218	0	5	700–707	4
6	248–251	1	6	219–222	1	6	708–715	9
7	252–255	3	7	223–226	2	7	716–723	15
8	256–259	3	8	227–230	2	8	724–731	14
9	260–263	5	9	231–234	7	9	732–739	8
10	264–267	1	10	235–238	6	10	740–747	7
11	268–271	6	11	239–242	10	11	748–755	5
12	272–275	4	12	243–246	7	12	756–763	0
13	276–279	5	13	247–250	10	13	764–771	1
14	280–283	3	14	251–254	6			
15	284–287	1	15	255–258	5			
16	288–291	5	16	259–262	0			
17	292–295	1	17	263–266	2			
18	296–299	0	18	267–270	3			
19	300–303	1	19	271–274	1			
			20	275–278	2			
			21	279–282	0			
			22	283–286	1			
No. of observations .		41	No. of observations .		66	No. of observations .		77
Centroid = 11·2683. $\mu_2 =$ 14·1678. $\sigma =$ 3·7640. $\mu_3 = -$ 21·2642. $\mu_4 =$ 638·4700. $\beta_1 =$ 0·1590. $\beta_2 =$ 3·1808. Critical function = − 0·115.			Centroid = 12·3030. $\mu_2 =$ 12·9536. $\sigma =$ 3·5991. $\mu_3 =$ 7·8225. $\mu_4 =$ 535·9122. $\beta_1 =$ 0·0281. $\beta_2 =$ 3·1938. Critical function = 0·303.			Centroid = 7·0519. $\mu_2 =$ 6·4497. $\sigma =$ 2·5396. $\mu_3 = -$ 4·3559. $\mu_4 =$ 111·3089. $\beta_1 =$ 0·0706. $\beta_2 =$ 2·6758. Critical function = − 0·860.		

The relationship between the "sides" is shown in the following scheme :—

Bone.	Sex.	No. of pairs.	Difference between the means of the R. and L. sides.	No. of pairs with the R. and L. bones differing from one another by less than 1 millim.	Per-centage.	No. of pairs with the R. bones greater than the L.	Per-centage.	Average pre-ponderance of R. over L.	No. of pairs with the L. bones greater than the R.	Per-centage.	Average pre-ponderance of L over R.
			millims.		per cent.		per cent.	millims.		per cent.	millims.
Ulna (2nd measurement)	♂	21	+1·95	0	0	17	80·9	2·72	4	19·0	1·28
	♀	28	+2·35	0	0	22	78·6	3·75	6	21·4	2·77

Here, again, we notice that the mean excess is greater in the female than in the male.

THE CLAVICLE.

The length of this bone, as we have previously seen, is highly variable. Some of the clavicles were strongly curved, but every transition occurred from an almost straight bone to one bent into the shape of an S. If we can form any opinion from the small number of pairs which were available we may say that the left clavicle tends to be longer than the right, while the left arm, as was shown above, is considerably shorter than the right. This relation, however, would appear to be much less constant in the clavicle than in the limb-bones.

Bone.	Sex.	No. of pairs.	Difference between the means of the R. and L. bones.	No. of pairs with the R. and L. bones differing from one another by less than 1 millim.	Per-centage.	No. of pairs with the R. bones greater than the L.	Per-centage.	Average pre-ponderance of R. over L.	No. of pairs with the L. bones greater than the R.	Per-centage.	Average pre-ponderance of L. over R.
			millims.		per cent.		per cent.	millims.		per cent.	millims.
Clavicle (maximum)	♂	19	−1·63	1	11·1	4	44·4	3·38	4	44·4	7·05
	♀	17	−1·40	6	35·3	3	17·6	1·53	11	64·7	2·59

According to these scant data the clavicle differs from the limb-bones in that the male has a greater mean excess than the female.

THE PROPORTIONAL LENGTHS OF THE LIMB-BONES—INDICES.

An index is a number which expresses the length of one dimension in terms of some other dimension measured on the same individual. Thus the absolute length disappears from consideration, and we have simply to deal with the varying proportion which the first dimension bears to the second.

I have already made use of indices in the case of each bone when the sexes were mixed. The curves thus obtained expressed the distribution of deviations about the mean ratio. These curves will be either simple or compound, according to whether the lengths of the bones in proportion to one another have the same or different means and standard deviations in the two sexes.

In Table XVI. are given most of the indices which have been suggested by different observers. The indices are of two kinds. From Table I. we can construct the limbs of a mean-man and of a mean-woman; the indices of these mean-individuals were then calculated, and they are thus indicated in the table. By such a method we can obtain no idea of the variability of the index. But we require to know what this variation is: for this purpose the index of each individual has been calculated separately, and so a series of indices are formed from which measures of variability may be obtained. The mean of the series will thus be the mean of the indices. In obtaining the series the question of "side" was disregarded. Strictly, this ought not to have been neglected, and especially is this the case with the bones of the arm, but it would have been impossible to have formed a sufficiently large series if this had not been done, on account of the fragmentary condition of the skeletons.

The standard deviation of one index is not necessarily comparable with that of another, for the standard dimension selected often differs in the various indices. On the other hand, the ratio-measures of variation (coefficients of variation) are comparable.

If we look down the two columns of coefficients, the one for the male and the other for the female, we shall see that the intermembral index is the least variable and the claviculo-humeral index the most variable in both sexes, and the female is somewhat more variable than the male. Of the intermediate indices the tibio-femoral, the humero-femoral, and the radio-humeral are more variable, and the radio-crural and humero-crural are less variable in woman than in man.

On the whole, then, we see that the relative proportions of the limb-bones are less constant in woman than in man, and so we should judge that the correlation between the bones would be less in the female than in the male, and this is exactly what we shall find when we come to consider the correlations.

Several varieties of the indices of the mean-individual are given. These were added to show the difference which is produced by measuring the lengths of the bones in different ways.

There is no doubt that for most purposes these numbers could be used for the conversion of indices, as obtained by different observers, into a comparable form, for it is doubtful whether race-differences would appreciably affect the relation between the various length-dimensions which have been adopted by different anatomists.

Having thus discussed the variability of the indices (and this, perhaps, is not very different in the various races), we will now turn to the actual mean values which have been determined, that is, to the ethnological side of the subject.

TABLE XVI.

Index.	Males.	Index of mean-man, and mean of indices.	Standard deviation.	Co-efficient of variation.	Females.	Index of mean-woman, and mean of indices.	Standard deviation.	Co-efficient of variation.
INTERMEMBRAL INDEX.								
$\frac{\text{H. (oblique) + R. (centre to centre)}}{\text{F. (oblique) + T. (centre to centre)}}$	Mean-man	68·849			Mean-woman	68·239		
$\frac{\text{H. (oblique) + R. (maximum)}}{\text{F. (oblique) + T. (centre to centre)}}$	Mean-man	70·508			Mean-woman	69·839		
$\frac{\text{H. (maximum) + R. (maximum)}}{\text{F. (maximum) + T. (centre to centre)}}$	27 Mean-man	70·587 70·730	1·514	2·133	50 Mean-woman	70·038 69·812	1·621	2·314
TIBIO-FEMORAL INDEX.								
$\frac{\text{T. (centre to centre)}}{\text{F. (oblique)}}$	Mean-man	80·090			Mean-woman	79·518		
$\frac{\text{T. (centre to centre)}}{\text{F. (maximum)}}$	86 Mean-man	79·808 79·506	1·970	2·469	109 Mean-woman	78·518 78·751	1·957	2·493
HUMERO-FEMORAL INDEX.								
$\frac{\text{H. (maximum)}}{\text{F. (maximum)}}$	Mean-man	71·016			Mean-woman	70·062		
$\frac{\text{H. (maximum)}}{\text{F. (oblique)}}$	Mean-man	71·538			Mean-woman	70·747		
$\frac{\text{H. (oblique)}}{\text{F. (oblique)}}$	48 Mean-man	70·712 70·618	2·022	2·860	75 Mean-woman	69·996 70·112	2·181	3·116

TABLE XVI—(continued).

Index.	Males.	Index of mean-man, and mean of indices.	Standard deviation.	Co-efficient of variation.	Females.	Index of mean-woman, and mean of indices.	Standard deviation.	Co-efficient of variation.
RADIO-HUMERAL INDEX.								
$\frac{\text{R. (centre to centre)}}{\text{H. (oblique)}}$	Mean-man	75·579			Mean-woman	74·725		
$\frac{\text{R. (maximum)}}{\text{H. (maximum)}}$	34 Mean-man	79·462 78·782	2·145	2·700	65 Mean-woman	77·867 78·113	2·273	2·920
RADIO-CRURAL INDEX.								
$\frac{\text{R. (centre to centre)}}{\text{F. (oblique) + T. (centre to centre)}}$	Mean-man	29·636			Mean-woman	29·184		
$\frac{\text{R. (maximum)}}{\text{F. (oblique) + T. (centre to centre)}}$	Mean-man	31·295			Mean-woman	30·783		
$\frac{\text{R. (maximum)}}{\text{F. (maximum) + T. (centre to centre)}}$	38 Mean-man	31·171 31·046	0·832	2·668	54 Mean-woman	30·735 30·617	0·727	2·366
HUMERO-CRURAL INDEX.								
$\frac{\text{H. (oblique)}}{\text{F. (oblique) + T. (centre to centre)}}$	Mean-man	39·213			Mean-woman	39·055		
$\frac{\text{H. (maximum)}}{\text{F. (maximum) + T. (centre to centre)}}$	49 Mean-man	39·412 39·562	1·172	2·974	72 Mean-woman	39·058 39·195	1·128	2·888
CLAVICULO-HUMERAL INDEX.								
$\frac{\text{Cl. (maximum)}}{\text{H. (oblique)}}$	Mean-man	47·162			Mean-woman	46·239		
$\frac{\text{Cl. (maximum)}}{\text{H. (maximum)}}$	19 Mean-man	46·734 46·555	1·990	4·258	29 Mean-woman	46·460 45·824	2·127	4·580

F. = Femur. T. = Tibia. H. = Humerus. R. = Radius. Cl. = Clavicle. The indices are multiplied by 100.

(1.) *The Intermembral Index.*

The upper limb, in proportion to the lower limb, is longer in man than in woman. In the data given by TURNER this index was calculated from the maximum length of the bones, except in the case of the tibia, where the spine was excluded. The indices of our mean-man and mean-woman, found from corresponding measurements, are 69·55 and 68·56 respectively. The mean index given for Europeans is 69·5, and a similar index is assigned to Mongolians, Malays, natives of India, &c.

(2.) *The Tibio-femoral Index.*

The tibia, in proportion to the femur, is shorter in woman than in man. The mean indices (the maximum length of the femur was taken and the spine was excluded from the tibia) are 82·67 for the male and 82·06 for the female. TOPINARD gives 81·1 as the mean of 55 European men, and 80·8 as the mean of 17 European women. To judge from some rather divergent results of different authors, Negroes would appear to have a mean index of about 84.

The value of this index varies much in the different races. TURNER gives the index 83 "as marking the division between proportionally long-legged ('dolichoknemic') and short-legged races ('brachyknemic')." According to this, the New Race were brachyknemic, and under this division are included Europeans, Chinese, Esquimaux, &c.

(3.) *The Humero-femoral Index.*

The length of the humerus, in proportion to that of the femur, is greater in man than in woman. Our indices for maximum humerus and maximum femur are 71·02 for the men and 70·06 for the women. Here the New Race diverge from the Europeans (index = 72·5) and resemble the black races (Negroes have an index = 71·3) where the humerus, in proportion to the femur, is shorter than in Europeans.

(4.) *The Radio-humeral Index.*

The length of the radius, in proportion to that of the humerus, is greater in man than in woman. For the maximum length of both bones the male index of the New Race was 78·78 and the female 78·11.

From 55 European male skeletons TOPINARD obtained a mean index 73·0, and from 26 female skeletons an index 72·4.

Sir WILLIAM TURNER divides the different races into three groups according to the value of this index. He applies the term *brachykerkic* to those races which have an index below 75 (such as Europeans, Lapps, &c.), *mesatikerkic* to those with an index between 75–79 (Australians, Negroes, American Indians, &c.), and *dolichokerkic* to those with an index of 80 and upwards (Andaman Islanders, Fuegians). Following this classification the New Race belongs to the bottom of the mesatikerkic division, which includes the black races and some yellow races.

(5.) *The Claviculo-humeral Index.*

In the New Race the relative length of the clavicle to the humerus would appear to be slightly greater in man than in woman. But M. PAUL BROCA has measured 9 Negroes and 7 Negresses, and the indices were 45·8 and 47·4 respectively, while in 5 European men and 4 women they were 44·3 and 45·0 respectively. In the case of the New Race the mean of the indices of 19 men was 46·73 and of 29 women 46·46. Here again, as in the radius, the New Race approached the Negro. To judge from TURNER'S measurements very considerable differences appear to occur in the value of this index for different races, and this author is inclined to think that the relation is too indefinite to form a race-character. Such we should expect from the highly variable nature of the clavicle, in fact, the coefficient of variation of this bone is much higher than that of any of the limb-bones.

(6.) *The Radio-crural and Humero-crural Indices.*

The indices which I have so named, indicate that both the radius and the humerus are longer in proportion to the femur + tibia in man than in woman. Below is a table quoted from TOPINARD, and derived from the measurements made by BROCA, on some 9–15 skeletons. In the third column are inserted the indices for the New Race.

Index.	Europeans.	New Race.	Negroes.
Humerus + radius : femur + tibia = 100	69·73	69·05	68·27
Radius : humerus = 100	73·93	78·45	79·40
Radius : femur + tibia = 100	29·54	30·34	30·38
Humerus : femur + tibia = 100 . . .	40·11	38·64	38·20
Clavicle : humerus = 100	44·63	46·19	46·74

In this table the sexes are mixed.

The values for the New Race lie in every case between the values given for Europeans and Negroes, but generally much nearer the latter than the former.

THE CORRELATION OF THE LENGTHS OF THE BONES.

By "correlation" we mean the relation which exists between two or more "effects," such that when the "cause" of variation produces a certain deviation from the mean of one effect then a simultaneous deviation is observed in all the other effects.

Take the case of two bones of the lower extremity. Let us suppose that a certain cause or system of causes acting on a group of still growing femora ultimately produces in them an average deviation from the mean length of femora in general. We then require to know what average deviation in the length of the tibiæ, say, is associated with this abnormal group of femora, that is, how the cause of variation in the group of femora influences the mean length of the tibiæ. Of course, we may state the problem in the reverse manner, and say that we require to know how the cause of variation in a group of tibiæ affects the mean length of the femora.

The causes, which are generally altogether unknown, need not necessarily be regarded. We have simply to deal with the effects and to express in a numerical manner the relation which is observed between them.

The application of a measure which will express the relation existing between two correlated organs is due to Mr. GALTON. A group of dimensions is chosen in which one organ varies between narrow and fixed limits. Now if the average deviation of this group from the general mean of the organ be expressed in terms of an absolute measure of variability of that organ, and if the observed associated mean deviation of the second organ be similarly expressed in terms of its variability, then the ratio of the latter to the former is practically constant, whatever group may be selected. This is only strictly true when the distribution of deviations follows the normal law.

This fraction (known as r) is the measure we require, for if the mean deviation of the first organ ("the subject") involves an equal (*i.e.*, "equal" in proportion to the variability of the organ) average deviation in the second ("the relative"), then our ratio becomes unity. As it involves less and less deviation in the second organ, the numerator of the fraction gradually approaches zero, and the constant r can thus have any value from ± 1 to 0.

The best method of determining r is by means of the formula $r = \frac{\Sigma xy}{n\sigma_1\sigma_2}$, which we have already explained. By the use of this formula the whole of the observations are taken into account. Having found r, we see, as before, that if $D =$ the average deviation from the mean of a group of femora, then the associated mean deviation of the tibiæ, say, will be equal to $r \frac{\sigma_2}{\sigma_1} D$, where σ_1, σ_2, are the standard deviations of femur and tibia respectively. The dispersion of these tibiæ about their mean will be measured by the standard deviation $\sigma_2 \sqrt{1 - r^2}$.

With respect to the dimensions of organisms, there are two problems which require to be solved, namely (1) the form of distribution of the *absolute variations* and (2) that of the *index variations*, and corresponding to these the *absolute correlations* and the *index correlations*. These are two quite distinct aspects of the question.

Suppose we had a series of men ranging in stature from pigmies to giants, and that they were all perfect models of one another, then the *absolute variation* of any bone would possess an extensive range, and the frequencies could be expressed by some form of curve; while the *absolute correlation* for every pair of bones would be expressed by unity. But let us take stature as the standard, and refer the measures to it; we shall then find no variation, and so the *index variation* and the *index correlation* are zero.

Next, suppose that we had a series of men of identical stature, but that the bones varied considerably in relation to one another. Here, since the standard is constant, the absolute variation would give the same curve as the index variation, and the absolute and index correlations must also be the same.

If we suppose in our former series ranging from pigmies to giants that the individuals were nearly, but not quite, perfect models of one another, then the absolute variations would have an extensive range, and the coefficients of correlation must still be high. The index variations would possess a small range, while the index coefficients of correlation might be either high or low.

If the individuals are supposed to only roughly resemble one another, then the absolute variations would give one form of frequency curve, while the index variations would very possibly give a quite different kind of curve, for the abnormal bones with respect to stature would be placed in their appropriate places towards either end of the series, while, of course, in the absolute series these bones might have been perfectly average ones. Similarly the absolute and index coefficients of correlation need not resemble one another, and there is no means of saying, *à priori*, whether the latter would be higher or lower than the former.

The absolute correlation of pairs of bones will give us a measure of how the bones in general are associated together, and this without reference to any particular standard we may wish to institute for the individual.

The form of frequency curve given by indices will partly depend upon the selected standard. The standard to which the organs are referred will be different according to the purpose we have in view. In the case of organisms that are still growing, we are unable to deal with the absolute measures, and we ought to select a standard which will represent as correctly as possible the stage of growth at which the animal has arrived.

When growth has ceased the significance of index variation and index correlation will depend upon the standard which is chosen. Here we shall generally require a dimension which stands in some functional relation to the organs; for example, tall men would find it very inconvenient to have exceptionally short arms, and so stature would be a suitable standard to which the bones of the arm might be referred. In this example, then, a correlation between the indices $\frac{\text{Length of arm}}{\text{Stature*}}$, $\frac{\text{Length of leg}}{\text{Stature*}}$, is intended to answer such a question as: What relative length of leg to stature will a man probably have when his arm, in proportion to stature, varies by a certain amount?

---

* The length of the vertebral axis would be better, so as to avoid the incidental correlation due to the length of the leg.

Professor **Pearson** has recently pointed out that if the bones were supposed to be sorted into skeletons absolutely at random, still a correlation would occur between the indices. The value thus obtained is called the "spurious correlation," and it would appear to be measured by the expression $\frac{v_3^2}{\sqrt{v_1^2 + v_3^2}\sqrt{v_2^2 + v_3^2}}$, where v_1, v_2, v_3, are the coefficients of variation of the two correlated dimensions and of the standard respectively. If ρ is the coefficient of correlation obtained from the actual indices, and ρ_0 is the "spurious correlation," the question arises as to whether any meaning can be assigned to the expression $\rho - \rho_0$. Professor **Pearson** is inclined to think that this expression gives the intensity of "organic correlation," as distinguished from the observed correlation.

The Absolute Correlations.

In Table XVII. are given the coefficients of correlation of pairs of bones for the male and female series.

The correlation of right and left bones is seen to be slightly less in the female than in the male in the case of the femur and tibia, but the right and left humerus and the right and left radius are perhaps somewhat more closely correlated in the female than in the male. Thus, with regard to right and left correlation, the female would seem to be more closely correlated than the male in the upper extremity, but less so in the lower. In every other case the coefficients of correlation are conspicuously greater in the male than in the female. The mean of the sexual ratios (♂/♀) of the correlations is 1·068.

The femur and tibia are very closely correlated; the former in the male would appear to be about equally correlated with the humerus and radius, but on comparing the male and female series it may perhaps be said that the femur is slightly less correlated with the radius than with the humerus. In the case of the tibia, on the other hand, there is apparently a somewhat stronger correlation with the radius than with the humerus. Perhaps we ought to expect this from the fact that the femur and humerus, and the tibia and radius, are serially homologous.

Everywhere, except in the case of the humerus and radius, the maximum length of the humerus is seen to be a little more strongly correlated with the other bones than is the oblique length of the humerus. Both in the male and female series the oblique length of the humerus is the dimension which is the more closely correlated with the radius. I have already suggested the reason for this in discussing the relation between the two lengths of the humerus.

In all these correlations, when a right bone was not present a left was taken. This, in the case of the arm-bones, is scarcely legitimate, as we can see from the

TABLE XVII.

Pairs of bones.	Male series.			Female series.		
	No. of individuals.	r.	Probable error of r.	No. of individuals.	r.	Probable error of r.
R. femur and L. femur (oblique)	48	0·9765	0·0032	66	0·9618	0·0045
Femur (oblique) and tibia (centre to centre) . . .	88	0·9164	0·0085	116	0·8487	0·0133
„ „ humerus (maximum)	63	0·8416	0·0190	98	0·7815	0·0209
„ „ „ (oblique)	63	0·8330	0·0200	98	0·7680	0·0222
„ „ radius (centre to centre) . .	42	0·8465	0·0225	64	0·7014	0·0351
R. tibia and L. tibia (centre to centre)	63	0·9634	0·0044	100	0·9505	0·0047
Tibia (centre to centre) and humerus (maximum) .	74	0·8497	0·0155	96	0·7842	0·0208
„ „ „ „ (oblique) . .	74	0·8396	0·0164	96	0·7835	0·0209
„ „ „ radius (centre to centre)	57	0·8505	0·0188	76	0·8078	0·0209
R. humerus and L. humerus (maximum)	33	0·9454	0·0091	52	0·9643	0·0047
„ „ „ (oblique)	33	0·9284	0·0119	52	0·9551	0·0059
Humerus (maximum) and radius (centre to centre) .	50	0·8232	0·0237	78	0·7745	0·0241
„ (oblique) and radius (centre to centre) .	50	0·8487	0·0203	78	0·7887	0·0227
R. humerus (oblique) and R. radius (centre to centre)	24	0·8605	0·0271	35	0·8185	0·0291
R. radius and L. radius (centre to centre)	21	0·9246	0·0157	27	0·9322	0·0124
Clavicles (maximum) and humerus (oblique) . . .	35	0·6767	0·0512	42	0·5349	0·0655

		No. of individuals.	r.	Probable error of r.
Sexes mixed	R. clavicle and L. clavicle (maximum)	32	0·9317	0·0115
	Clavicle and infraspinous index . . .	20	0·3630	0·1231

Mean of the sexual ratios (♂/♀) of all the correlations = 1·068.

example, where the R. humerus is correlated with the R. radius. This can readily be understood from the considerable asymmetry which was found between the arm-bones of the two sides. If "side" had been regarded throughout the series, the number of available bones would have been so much reduced that I considered it best to disregard this source of error altogether, but it should be borne in mind that in the correlations of the bones of the arm the coefficients are slightly smaller than if the "side" of the bones could have been taken into account. Taking everything into consideration, however, the bones of the lower extremity (the femur and tibia) would appear to be distinctly more strongly correlated than are the corresponding bones of the arm (the humerus and radius). It is remarkable that the femur and tibia should be about as strongly correlated with the humerus and the radius as the latter bones are with each other.

The length of the clavicle and the proportional breadth of the scapula to the infraspinous length would seem to be slightly correlated, but the probable error of the coefficient is here very large, and hence little reliance can be placed on the actual value obtained.

The Index Correlations.

The significance of these correlations has already been discussed. The standards which were instituted were not very satisfactory. Undoubtedly stature (or rather the length of the vertebral axis) would have been the best, but, of course, this was not available. Consequently it was necessary to take one bone as the standard, and to express pairs of other bones in terms of it. Whenever possible the length of the tibia, excluding the spine, was selected.

The results which have been obtained are given in Table XVIII. Besides the coefficients of correlation* (ρ), I have added the "spurious correlations" (ρ_0) which were determined by Professor PEARSON's formula. This formula has already been mentioned. In the last column to the right the value $\rho - \rho_0$ is shown. As an example, let us take the first pair of indices given in the table. The probable deviation from the mean of the ratio $\frac{\text{L. femur}}{\text{Tibia}}$ associated with a known deviation (D) of the ratio $\frac{\text{R. femur}}{\text{Tibia}}$ is given by $\rho \frac{\sigma_2}{\sigma_1} \text{D} = \cdot 9 \frac{2\cdot 48}{2\cdot 57}$ D, but whether the "organic correlation" between the indices is represented by $\rho - \rho_0 = \cdot 342$ rather than by $\rho = \cdot 9$ is an open question.

Confining ourselves to the actually observed correlations of the ratios, we see that many of the coefficients differ very widely from those obtained from the absolute measures. In nearly every case they are distinctly lower. No uniform difference between the correlations of the male and female can be detected. One point, however, comes out very clearly: the femur and humerus expressed in terms of the tibia are more strongly correlated than the femur and radius referred to the same standard. This was less distinctly shown in the absolute correlations. Also the tibia and radius, with the humerus as the standard, are more closely correlated than the tibia and the humerus expressed in terms of the femur, and with the absolute correlations similar results were obtained. According to the expressions $\rho - \rho_0$, this condition of things is reversed.

The Correlation of Homologous Parts.

Since the foregoing was written I have been enabled to test the hypothesis of the closer correlation of homologous parts by a comparison with two other races, the Aino and the French. This has been possible through the great kindness of Miss

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* These were found by the direct correlation of the ratios.

TABLE XVIII.

Pairs of indices.									No. of obser-vation.	Coeffi-cient of corre-lation ρ.	Pro-bable error of ρ.	"Spu-rious corre-lation", ρ_0.	$\rho - \rho_0$.
Sex.	Index.	Mean.	Stand-ard devia-tion.	Coeffi-cient of varia-tion.	Index.	Mean.	Stand-ard devia-tion.	Coeffi-cient of varia-tion.					
♂	$\frac{\text{R. femur (oblique)}}{\text{Tibia + malleolus}}$	119·685	2·574	2·151	$\frac{\text{L. femur (oblique)}}{\text{Tibia + malleolus}}$	119·789	2·484	2·073	43	0·900	0·0145	0·558	0·342
♀	,,	121·362	2·829	2·331	,,	121·700	2·870	2·359	64	0·912	0·0123	0·554	0·358
♂	$\frac{\text{Femur (oblique)}}{\text{Humerus (oblique)}}$	142·473	4·456	3·127	$\frac{\text{Tibia (centre to centre)}}{\text{Humerus (oblique)}}$	114·279	3·991	3·493	52	0·749	0·0329	0·442	0·307
♀	,,	143·596	4·387	3·055	,,	113·730	3·856	3·390	73	0·624	0·0408	0·443	0·181
♂	$\frac{\text{Femur (oblique)}}{\text{Tibia + malleolus}}$	119·680	2·662	2·224	$\frac{\text{Humerus (oblique)}}{\text{Tibia + malleolus}}$	84·215	2·558	3·038	47	0·439	0·0727	0·526	−0·087
♀	,,	121·520	3·248	2·673	,,	84·903	2·670	3·145	74	0·407	0·0606	0·576	−0·169
♂	$\frac{\text{Femur (oblique)}}{\text{Tibia + malleolus}}$	120·053	2·567	2·138	$\frac{\text{Radius (centre to centre)}}{\text{Tibia + malleolus}}$	63·936	1·775	2·776	37	0·287	0·0978	0·514	−0·227
♀	,,	121·634	3·167	2·603	,,	63·583	1·727	2·716	57	0·330	0·0756	0·524	−0·194
♂	$\frac{\text{R. tibia (centre to centre)}}{\text{Femur (oblique)}}$	80·163	1·850	2·308	$\frac{\text{L. tibia (centre to centre)}}{\text{Femur (oblique)}}$	80·302	1·699	2·116	49	0·908	0·0125	0·479	0·429
♀	,,	79·350	2·072	2·612	,,	79·625	2·019	2·535	76	0·947	0·0058	0·444	0·503

TABLE XVIII. (continued).

Pairs of indices.									No. of observation.	Coefficient of correlation ρ.	Probable error of ρ.	"Spurious correlation" ρ_0.	$\rho - \rho_0$.
Sex.	Index.	Mean.	Standard deviation.	Coefficient of variation.	Index.	Mean.	Standard deviation.	Coefficient of variation.					
♂	$\frac{\text{Tibia (centre to centre)}}{\text{Femur (oblique)}}$	80·400	1·747	2·170	$\frac{\text{Humerus (oblique)}}{\text{Femur (oblique)}}$	70·712	2·022	2·860	48	0·083	0·0963	0·488	−0·405
♀	,,	79·134	2·169	2·741	,,	69·996	2·181	3·116	75	0·341	0·0651	0·464	−0·123
♂	$\frac{\text{Tibia (centre to centre)}}{\text{Humerus (oblique)}}$	113·601	3·361	2·958	$\frac{\text{Radius (centre to centre)}}{\text{Humerus (oblique)}}$	75·753	1·893	2·499	37	0·476	0·0774	0·437	0·039
♀	,,	113·186	3·495	3·088	,,	74·709	2·091	2·785	63	0·564	0·0505	0·470	0·093
♀	$\frac{\text{R. humerus (oblique)}}{\text{Tibia + malleolus}}$	85·570	2·640	3·085	$\frac{\text{L. humerus (oblique)}}{\text{Tibia + malleolus}}$	83·703	2·642	3·156	37	0·950	0·0078	0·572	0·378
♀	$\frac{\text{Humerus (oblique)}}{\text{Tibia + malleolus}}$	85·233	2·547	2·988	$\frac{\text{Radius (centre to centre)}}{\text{Tibia + malleolus}}$	63·637	1·769	2·786	60	0·559	0·052	0·457	0·102
Sexes mixed	$\frac{\text{R. radius (centre to centre)}}{\text{Tibia + malleolus}}$	63·999	1·964	3·070	$\frac{\text{L. radius (centre to centre)}}{\text{Tibia + malleolus}}$	63·313	1·957	3·092	41	0·902	0·0146	0·468	0·434
♀	$\frac{\text{Clavicle}}{\text{Tibia + malleolus}}$	39·735	2·078	5·229	$\frac{\text{Humerus (oblique)}}{\text{Tibia + malleolus}}$	84·990	2·460	2·895	42	0·419	0·0791	0·522	−0·103
Sexes mixed	,,	40·143	2·041	5·084	,,	85·300	2·609	3·058	68	0·423	0·0618	..	..

ALICE LEE and Professor PEARSON, in allowing me to use the results which they have obtained in the correlation of the limb-bones of these two races.

In Table XVIIIA. we have a comparative view of the coefficients of correlation for the three races. From the column headed "Mean of the six r's" we can see that the femur and the tibia are more strongly correlated than the humerus and the radius. Also the femur and the humerus, which are homologous bones in the lower and upper extremities respectively, are distinctly more closely correlated than the femur and the radius, which are not serially homologous. Similarly the tibia and the radius would appear to be slightly more correlated than the tibia and the humerus. It will be noticed, however, that in the French this tendency for the closer correlation of homologous parts is not exhibited in the case of the correlations of the tibia.

Omitting the French and taking the means of the correlations of the other two races, we obtain the results given in the succeeding column of the table. The difference between the mean correlations of the femur and tibia and the humerus and radius is 8·1 per cent. of perfect correlation; the difference between the femur and humerus (homologous bones) and the femur and radius (non-homologous bones) is 7·8 per cent., while with the tibia and radius and the tibia and humerus the difference is only 4·1 per cent.

A much larger series would be necessary before any certain conclusions could be drawn, but the following suggestions are offered:—

(1.) The bones of the upper extremity are less correlated with one another than are the corresponding bones of the lower extremity; *e.g.*, the mean correlation of femur and tibia = 0·86, and of humerus and radius = 0·78.

(2.) Serially homologous bones tend to be more closely correlated than non-homologous bones, but perhaps this is less marked in civilised than in savage races.

(3.) Proximal bones would seem to be more correlated than distal bones; *e.g.*, the mean correlation of femur and humerus = 0·84, and of tibia and radius = 0·82.*

II. THE SACRUM.

It was previously stated that this bone was found to be useless for the determination of sex.

Many of the sacra were in such a fragmentary condition that nothing could be inferred from them.

There was considerable variation in the number of constituent vertebræ. Out of 264 sacra examined there were seven (2·65 per cent.) composed of four vertebræ, and in four more bones this was doubtfully the case. Of these eleven sacra six belonged to female skeletons, two to male skeletons, while the sex of the remaining three was

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* I have not touched upon the comparative strength of the correlation in the three races, since Professor PEARSON is investigating this subject.

TABLE XVIIIA.

Absolute correlations.

Bones.*	Male.						Female.						Mean of the six r's.	Mean of the four r's, excluding the French.	‡
	Aino.		New Race.		French.		Aino.		New Race.		French.				
	No.	r.	No.	r.	No.	r.	No.	r.	No.	r.	No.	r.			
Femur and tibia	40	0·8266 ±0·0260†	88	0·9164 ±0·0085	50	0·8058 ±0·0261	24	0·8457 ±0·0299	116	0·8487 ±0·0133	50	0·8904 ±0·0148	0·8556	0·8593	0·0811
Humerus and radius . .	39	0·7763 ±0·0338	50	0·8232 ±0·0237	50	0·8451 ±0·0208	22	0·7386 ±0·0526	78	0·7745 ±0·0241	50	0·8515 ±0·0200	0·8015	0·7782	
Femur and humerus . .	42	0·8584 ±0·0208	63	0·8416 ±0·0190	50	0·8421 ±0·0212	23	0·8722 ±0·0254	98	0·7815 ±0·0209	50	0·8718 ±0·0173	0·8446	0·8384	0·0782
„ and radius . . .	37	0·7891 ±0·0328	42	0·8465 ±0·0225	50	0·7439 ±0·0341	22	0·7039 ±0·0593	64	0·7014 ±0·0351	50	0·7786 ±0·0296	0·7606	0·7602	
Tibia and radius . . .	35	0·8655 ±0·0216	57	0·8505 ±0·0188	50	0·7804 ±0·0294	21	0·7452 ±0·0525	76	0·8078 ±0·0209	50	0·8053 ±0·0261	0·8091	0·8173	0·0407
„ and humerus . . .	39	0·7447 ±0·0257	74	0·8497 ±0·0155	50	0·8601 ±0·0188	22	0·7277 ±0·0547	96	0·7842 ±0·0208	50	0·8180 ±0·0244	0·7974	0·7766	
Clavicle and humerus . .	34	0·4393 ±0·0855	35	0·6767 ±0·0512	..	..	20	0·6309 ±0·0768	42	0·5349 ±0·0655	..	..	..	0·5704	

* The length-measurements taken on the bones were not identical in the three races, but it is very improbable that this fact would alter the relations here observed—

In the Aino— Femur (maximum), tibia (centre to centre), humerus (maximum), radius (maximum), clavicle (maximum).
In the New Race— „ (oblique), „ „ „ (oblique), „ (centre to centre), „ „
In the French— „ (maximum), „ (excluding spine), „ (maximum), „ (maximum), „ „

† These are the probable errors of r.

‡ The difference between the mean correlations obtained from the two savage races, the Aino and the New Race.

undetermined. In sixteen cases (6·06 per cent.) the sacrum was composed of six vertebræ, but as the rest of the vertebral column was incomplete, it was impossible to say whether this condition was attained by the fusion of the last lumbar or the first caudal. Here five were male, seven female, and the rest undetermined. There were also sixteen (6·06 per cent.) other sacra, composed of six vertebræ, but the most anterior one was imperfectly assimilated with the remaining five, and the sacrum exhibited two promontories (see Plate 22, fig. *S.* 1102). Of these, five were male and six female. In six cases (2·27 per cent.) there were five vertebræ, but the anterior one was similarly imperfectly assimilated with the remaining four; one belonged to a male skeleton, and three to female skeletons. In four cases (1·51 per cent.) the anterior vertebra was free on one side, while on the other side it was completely fused with the rest of the sacrum, and the auricular surface extended over it. The actual number of vertebræ in these sacra was undetermined, as every specimen was much damaged.

Many of the sacra exhibited a marked right and left asymmetry. Here it was observed that the auricular surface generally extended forwards unequally on either side. The sacra which possessed two promontories showed, as a rule, this asymmetry to a greater or less degree.

A very remarkable feature in the sacra was the frequency with which a completely open sacral canal occurred. In no less than eight cases (3·03 per cent.) was the canal widely open throughout its entire length, while in another case it was open except for the neural arch of the first sacral vertebra. In four cases the canal was open posteriorly from a half to two-thirds of its length. Of these thirteen sacra nine belonged to male skeletons, and two to female.

As far as can be judged from these comparatively few observations, it would appear that the female exhibits diminution in the number of constituent vertebræ more frequently than does the male, while, on the other hand, the open neural canal would seem to be an essentially male abnormality.

Dr. A. M. PATERSON* has examined 265 adult sacra of both sexes and of various races. He found only one specimen consisting of four vertebræ (0·37 per cent.), while increase above five vertebræ occurred in 35·46 per cent. In the New Race diminution to four vertebræ was found in 2·65 per cent. at least, while increase above five occurred in only 12·12 per cent. Thus the sacra of the New Race differed perceptibly from the collection examined by PATERSON. But it is impossible to know from this observer's material whether modern races differ among themselves in the proportional number of abnormal sacra. From our results it would seem probable that different races do vary very considerably in this respect, for it would be rash to admit that a tendency is here shown towards an elongation of the modern sacrum.

Dr PATERSON has drawn attention to the "sacral notch" as being a simian character, and he found it in a considerable percentage of the sacra of certain races. The notch is occasioned by the second sacral vertebra being somewhat narrower from right to left than the first and third. There fits into this notch a protuberance of the ilium, and so the sacrum and the pelvic girdle are more firmly locked together. The sacral notch was not at all conspicuously exhibited in any of our sacra, though, in a few cases, traces of it could be observed.

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* 'Trans. Roy. Dublin Soc.,' 1893.

THE MEASUREMENTS OF THE SACRUM.

Only the normal sacra, composed of five vertebræ, were measured. Two dimensions were taken, the length and the breadth.

The length was measured from the middle of the promontory to the middle of the ventral border of the fifth vertebra. The breadth was the greatest transverse diameter as measured by two parallel and vertical surfaces.

From these dimensions the ordinary sacral index was calculated $\frac{\text{Breadth} \times 100}{\text{Length}}$. The results are given in the accompanying table (XIX.).

Here we have the anomalous result of the male sacrum being relatively broader than the female bone. I attribute this to the great curvature which many of the male sacra exhibited, while a considerable number of the female sacra were nearly flat (see Plate 22, figs. *S.* 1212; *S.B.* 112). Such a curvature will reduce the "length" very appreciably, and so the sacral index will become high. It would appear to be a more satisfactory method to measure the "length" along the mid-line of the ventral concave surface, and then the effect of curvature would disappear from the index.

Little stress, however, can be placed on the actual difference observed between the means of the male and female series, for the probable error of the mean is over one-hundredth of "length" in each case. It will be noticed that woman is considerably more variable in the sacral index than man.

From Table XX. we see that the mean length of the sacrum in absolute measures is a trifle greater in the female than in the male, and this we can understand from the strong curvature of many of the male sacra and the comparative flatness of a considerable number of the female bones.

The breadth is a trustworthy measurement, and it will be seen that in absolute measures the female sacrum is very nearly as broad as the male, from which we may probably judge that if the "length" were measured along the curved surface, the female sacrum would be relatively broader than the male bone.

It would appear that length and breadth are more closely correlated in man than in woman.

Sir WILLIAM TURNER has divided the different races into the

(1.) *Dolichohieric*, with sacral index below 100; this is the most Simian group, and includes Kaffirs, Bushmen, &c.

TABLE XIX.

Sacral index $\frac{\text{Breadth}}{\text{Length}} \times 100$.

Male series.			Female series.		
Unit = 0·03 length.	Index.	Frequency.	Unit = 0·03 length.	Index.	Frequency.
1	96– 98	1	1	95– 97	3
2	99–101	2	2	98–100	1
3	102–104	1	3	101-103	5
4	105–107	0	4	104–106	3
5	108–110.	8	5	107–109	4
6	111–113	2	6	110–112	3
7	114–116	4	7	113–115	8
8	117–119	5	8	116–118	6
9	120–122	4	9	119–121	3
10	123–125	2	10	122–124	4
11	126–128	0	11	125–127	2
12	129–131	2	12	128–130	0
13	132–134	0	13	131–133	1
14	135–137	0	14	134–136	0
15	138–140	0	15	137–139	0
16	141–143	1	16	140–142	0
			17	143–145	2
No. of individuals		32	No. of individuals		45
Mean . . . . = 115·000. Standard deviation . . = 9·357. Coefficient of variation = 8·137.			Mean . . . . = 113·667. Standard deviation . . = 10·798. Coefficient of variation = 9·499.		

TABLE XX.

The correlation of length and breadth of the sacrum.

Sex.	No.	Dimension.	Mean.	σ.	ν.	Dimension.	Mean.	σ.	ν.	r.	Probable error of r.
♂	32	Length	97·450	8·767	8·996	Breadth	110·931	6·001	5·410	0·4637	0·0741
♀	45	„	98·100	9·420	9·602	„	110·333	6·287	5·699	0·3126	0·0866

(2.) *Platyhieric*, with the index above 100. This group has been further divided into—

- (*a*) *Subplatyhieric*, index 100–106, and including Australians, Negroes, Chinese, &c.
- (*b*) *Platyhieric*, index over 106, including Europeans, Ancient Egyptians.

We now see that the New Race was strongly platyhieric; TURNER quotes 112·4 as the mean male index for Europeans, and 116·8 as the mean female index. We may hence conclude that, in this character, the New Race closely resembled modern Europeans.

III. THE SCAPULA.

Unfortunately, only a small number of these bones could be measured, as the scapula is a bone peculiarly liable to injury.

When possible, I measured in all cases the total length in a straight line from the superior to the inferior angle, the breadth from both the centre of glenoid cavity and from the middle point of its dorsal edge to the point where the spine meets the vertebral border. I also measured the distance of this latter point from the inferior angle = "infraspinous length."

From these measurements we can derive two indices:—

$$\text{The scapular index } \frac{\text{Breadth to border}}{\text{Length}} \times 100.$$

$$\text{The infraspinous index } \frac{\text{Breadth to border}}{\text{Infraspinous Length}} \times 100.$$

The indices which were found are given in Table XXI.; the sexes and "sides" are mixed.

It would appear, however, that the mixture of sexes is not wholly justifiable, as may be seen from Table XXII. Here the means are higher in the female than in the male, indicating a greater proportional breadth to the scapula in woman than in man.

Table XXIII. gives the details as to the correlation between the infraspinous length and breadth in 44 scapulæ. There is seen to be a distinct, though not a very strong, correlation between these two dimensions.

It is a rather remarkable fact that length and breadth seldom appear to be closely correlated. We found it so in the sacrum, it is also the case in skulls, and I feel satisfied by observation that such will be found to be true for the long bones.

The mean of the scapular index is 65·9, and of the infraspinous index 89·4. These results are surprisingly close to the mean values given for Europeans, which are 65·3 and 87·8 respectively.

We have seen that the question of sex ought not strictly to be neglected; it would also seem that "side" should be taken into account. As far as we can judge from the few observations, it would appear that the means of total length and infraspinous length are practically the same on the two sides, but in every case in which a pair occurred, both in male and female, the breadth was greater on the left side than on the right, and so corresponded to the greater mean length of left clavicle. The average preponderance in four men was 1·59 millim., and in four women 1·60 millim.

The angle which the axis of the spine made with the vertebral border was very variable. I approximately measured two of the extreme cases; the angle which the axis of the spine made with the anterior portion of vertebral border was 72° and 86°. On the whole it may be said that this "scapulo-spinal angle" was somewhat low for the New Race; the mean given for Europeans is 82°·5.*

TABLE XXI.

Scapular index.			Infraspinous index.		
Unit = 0·01 total length.	Index.	Frequency.	Unit = 0·02 infraspinous length.	Index.	Frequency.
1	57	1	1	74–75	2
2	58	0	2	76–77	2
3	59	0	3	78–79	2
4	60	1	4	80–81	3
5	61	1	5	82–83	0
6	62	1	6	84–85	7
7	63	0	7	86–87	3
8	64	3	8	88–89	5
9	65	1	9	90–91	3
10	66	2	10	92–93	2
11	67	3	11	94–95	3
12	68	2	12	96–97	4
13	69	2	13	98–99	4
14	70	1	14	100–101	1
15	71	0	15	102–103	1
16	72	2	16	104–105	0
			17	106–107	1
			. . . .	. . . . .	. . .
			20	112–113	1
No. of individuals . . .		20	No. of individuals . . .		44
Mean . . . . = 65·900. Standard deviation . . = 3·815. Coefficient of variation = 5·789.			Mean . . . . = 89·454. Standard deviation . . = 8·572. Coefficient of variation = 9·583.		

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* See Sir William Turner's memoir, *op. cit.*

Table XXII.

Sex.	Six men.			
Index.	$\frac{\text{Breadth to margin}}{\text{Length}}$.	$\frac{\text{Breadth to centre}}{\text{Length}}$.	$\frac{\text{Breadth to margin}}{\text{Infraspinous length}}$.	$\frac{\text{Breadth to centre}}{\text{Infraspinous length}}$.
Mean of indices . . . . Index of mean-individual.	65·97 65·96	65·60 65·50	90·47 90·29	89·89 89·66
The absolute lengths from which the index of mean-individual was calculated	$\frac{103{\cdot}17}{156{\cdot}40}$	$\frac{102{\cdot}45}{156{\cdot}40}$	$\frac{103{\cdot}17}{114{\cdot}26}$	$\frac{102{\cdot}45}{114{\cdot}26}$
Sex.	**Nine women.**			
Index.	$\frac{\text{Breadth to margin}}{\text{Length}}$.	$\frac{\text{Breadth to centre}}{\text{Length}}$.	$\frac{\text{Breadth to margin}}{\text{Infraspinous length}}$.	$\frac{\text{Breadth to centre}}{\text{Infraspinous length}}$.
Mean of indices . . . . Index of mean-individual.	68·00 67·85	67·84 67·67	91·69 91·12	91·44 90·87
The absolute lengths from which the index of mean-individual was calculated	$\frac{93{\cdot}23}{137{\cdot}40}$	$\frac{92{\cdot}97}{137{\cdot}40}$	$\frac{93{\cdot}23}{102{\cdot}31}$	$\frac{92{\cdot}97}{102{\cdot}31}$

Table XXIII.

Correlation between infraspinous length and breadth of scapula (44 scapulæ).									
Dimension.	Mean.	σ.	v.	Dimension.	Mean.	σ.	v.	r.	Probable error of r.
Infraspinous length	109·818	9·933	9·045	Breadth	98·045	7·211	7·354	0·329	0·086

SUMMARY.

Some of the more important conclusions which we have arrived at may be briefly recapitulated in the following paragraphs:—

(1.) We have seen that the variability of the long bones is roughly proportional to their absolute length.

(2.) With respect to the long bones, I have been able to detect no appreciable difference between the variabilities of the two sides of the body.

(3.) The curves which the measurements of long bones yield would appear to be generally those of limited range.

(4.) The femora of the New Race were markedly pilastric. Some few were platymeric, but these mostly had an exceptionally low pilastric index.

(5.) The length of the neck + head of the femur in proportion to the total length of the bone is longer in man than in woman, but the angle of the neck with the shaft would appear to be somewhat greater, or at least not less, in the female than in the male.

(6.) It is suggested that the angle of torsion will be found to be a race character.

(7.) The oblique length of the femur, relative to the maximum length, is shorter in woman than in man. This is due to the greater width of the pelvis, and possibly there is a fairly strong correlation between the breadth of the pelvis and the angle which the condyles make with the horizontal plane when the bone is held upright in the maximum position.

(8.) The tibiæ of the New Race exhibited platycnemia to a marked degree, but it was found less frequently in the female than in the male. There were distinct indications of a correlation between the platycnemia of the tibia and the condition of the "pilastre" of the femur.

(9.) The humeri exhibited an intercondylar foramen with remarkable frequency. Perforation occurred more often in the female than in the male, and on the left side than on the right. I am inclined to agree with Dr. TOPINARD'S suggestion that the perforation in man is incidental.

(10.) The ulna was generally incurved to a greater or less degree.

(11.) The femur + tibia is slightly longer on the left side than on the right, but the right humerus + radius is very distinctly longer than the left, while, perhaps, the left clavicle and the left scapula with regard to its breadth are somewhat greater than the right. The asymmetry would appear to be more marked in woman than in man.

(12.) The New Race had an intermembral index lying between the indices assigned to Europeans and Negroes. This race was "brachyknemic" and distinctly "mesatikerkic." The radio-crural and humero-crural indices very remarkably approached the values given for Negroes by M. PAUL BROCA.

(13.) The *absolute correlations* of the bones differ very markedly from the *index correlations*. The latter in every case are smaller than the former. The "spurious correlations" are always approximately equal to 0·5. There are clear indications of a closer correlation between serially homologous bones than between non-homologous bones.

(14.) The sacrum was remarkable for the great curvature which many of the bones exhibited. This was more conspicuously shown in the male sacra, and consequently the "length" measurement was much reduced. As measured by the ordinary sacral index, the male sacrum was broader in proportion to its "length" than the female sacrum. The New Race were as strongly platyhieric as modern Europeans.

(15.) The scapular index is higher in the female than in the male. The scapulo-spinal angle would appear to be somewhat low.

Both the scapular and the infraspinous indices closely resemble those of Europeans.

Here, then, in the New Race we have a hardy and vigorous people, as shown by the pronounced pilastre of the femur and the platycnemia of the tibia. Just as is observed in so many races, in some characters the New Race was advanced or modern; in others it was inferior or primitive. On the whole, the proportions of the limb-bones to one another may be said to have approached those of the Negro, while the sacral and scapular indices were almost identical with those of Europeans.

THE TABLES OF THE LENGTH-MEASUREMENTS OF THE BONES.

The following tables include all the length-measurements made on the bones. They constitute, I believe, by far the largest series ever made on a single race.

The publication of this raw material may appear unnecessary, but when it is remembered that perhaps in the future some of the preceding analysis may be shown to be insufficient, then the great value of such material will be evident. Besides, the skulls have not as yet been exhaustively dealt with, and the vertebral columns (other than the sacra) and certain other parts of the skeletons still remain to be studied. Now, many very important correlations could be instituted when all the material has been thoroughly worked through, and some of these would be impossible without these tables.

In the preparation of the tables it was necessary to re-sort all the measurements into the respective skeletons, and the whole series has been very carefully revised. In a few cases I became doubtful as to whether a bone really belonged to the assigned skeleton; such are indicated by a query placed over the figures. On the other hand, a few additional bones had been overlooked; these have since been measured, and it has thus been possible to construct several more undoubted skeletons. When a second skeleton was found in a grave it is indicated by an x placed after the number.

These tables, then, represent a revision of the series from which the foregoing results have been calculated. The alterations are exceedingly few and quite inappreciable with respect to the values of the constants which have been determined. A few more skeletons have been added, and so the series is slightly more complete; also the right of several bones to the place assigned them has been questioned, and a few errors in transcription have been corrected. These errors were not of a serious nature: in three or four cases the "side" of the bone had been accidentally reversed, while in copying the figures only three mistakes were detected, and the greatest of these made a difference of 0·7 millim. in the measurement.

The graves from which the skeletons were taken were divided into four groups (the "General Graves," the "Q Graves," the "B Graves," and the "T Graves"), since they were more thickly scattered over certain four localities than over the intervening area.

The tables will mostly explain themselves. The "side" of the bones, which have their measurements placed along a horizontal line, is indicated by an R (right) or L (left) in the third column. When both "sides" occur in the same line, "R.L." is put in this column, and the "side" of each measure is shown by a little *r* or *l* placed before the figures.

At the end of each series there is placed a list of the bones which possessed the same number, but which, for certain reasons, could not be sorted into skeletons. Here the number found on the bones is placed first, and then the bones themselves are indicated by letters: F = femur; T = tibia; Fib = fibula; H = humerus; R = radius; U = ulna; Cl = clavicle; Sc = sacrum.

GENERAL GRAVES.—*Skeletons.*

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
1	?	R.	..	..	..	..	..	..	..	298·5	297·0	..	..	.	..	..	..	..	..	..	..
2	♀	R.L.	..	..	..	*l* 349·0	*l* 342·3	*l* 328·9	..	*r* 289·8	*r* 287·0	*r* 233·5	*r* 220·0	..	..	..	..	..	..	..	..
7	♀	R.L.	..	..	..	..	..	*l* 325·6	..	*l* 292·6	*l* 291·8	*l* 229·0	*l* 216·0	..	..	*r* 132·2	..	..	..	..	..
10	♀	L.	..	..	..	354·0	342·2	329·0	..	..	..	..	..	..	..	..	..	..	..	..	..
15	♀	R.	..	..	..	363·3	356·0	342·0	..	..	..	229·0	219·0	248·0	244·0	142·6	93·2	114·0	132·0	95·2	89·8
		L.	..	..	..	366·3	358·2	344·9	..	300·4	293·3	228·6	219·0	..	..	143·8	..	..	..	..	..
15E	?	L.	..	..	..	401·2	390·6	376·3	..	..	..	..	..	..	..	..	..	..	..	..	..
16	♂	R.	437·9	437·0	..	378·2	367·9	353·3	..	310·2	308·0	252·0	237·0	273·0	268·3	..	96·4	117·3	153·4	103·0	114·8
		L.	438·0	437·6	..	..	..	..	..	307·3	306·2	250·2	235·0	273·0	268·0	152·7	..	..	156·0	104·3	114·0
18	?	R.	..	..	..	..	..	..	..	..	..	258·8	247·2	277·5	275·3	..	..	..	..	..	..
20	?	L.	..	..	..	..	..	..	..	300·9	294·8	..	..	..	..	..	..	..	..	..	..
21	♂	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	88·0	105·4	..	..	..
22	♂	R.	..	..	..	..	..	..	389·0	335·0	325·4	262·0	248·3	287·0	282·8	159·7	..	..	..	..	..
		L.	..	..	..	..	..	..	..	328·2	322·8	..	247·0	284·8	280·8	166·2	..	..	..	..	..
25	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	139·3	..	..	..	..	..
26	♂	R.	444·3	439 2	..	380·5	372·3	359·5	..	..	..	..	..	263·0	255·0	..	..	..	..	..	..
		L.	442·0	437·0	..	379·2	370·9	358·2	368·0	317·1	315·8	241·2	226·0	259·5	254·1	..	..	..	..	..	..
27	?	R.L.	..	..	..	..	..	..	..	*l* 308·8	*l* 306·8	..	..	..	*r* 263·0	..	98·0	109·3	..	..	..
28	?	R.	..	..	..	..	..	..	..	..	..	236·4	224·7	261·3	256·0	137·8	87·0	109·8	..	..	..
		L.	..	..	..	..	..	..	..	293·4	292·2	230·0	218·0	..	250·0	..	..	..	..	..	..
30	♀	R.	403·8	400·4	..	..	..	..	..	294·5	294·5	241·2	228·3	259·0	255·0	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	289·4	289·3	236·8	223·5	254·2	250·8	140·6	..	..	..	..	..
31	?	R.L.	*l* 421·3	*l* 416·5	..	..	..	..	..	..	..	..	..	..	..	*r* 136·2	..	..	..	..	..
36	♀	R.	..	..	..	351·0	342·2	330·6	..	308·0	304·9	..	..	264·0	258·3	139·8	..	..	..	..	..
		L.	435·2	431·0	68·5	355·0	345·5	335·0	..	304·0	298·3	245·0	233·0	..	..	..	..	..	..	..	..
37	♂	R.	..	..	..	..	..	..	..	347·0	338·0	271·3	255·3	293·8	287·3	..	109·3	119·9	..	..	..
		L.	..	..	..	420·5	410·5	394·0	..	..	..	..	..	293·7	288·5	..	..	..	..	..	..
38	?	R.	445·8	441·2	..	..	..	..	..	325·4	316·8	..	..	..	..	..	..	..	..	..	..
		L.	445·3	440·1	..	..	..	..	..	317·2	..	..	..	..	..	..	..	..	..	..	..
40	?	R.L.	..	..	..	..	..	..	..	..	..	*l* 234·2	*l* 222·2	..	..	*r* 141·5	..	..	..	..	..
40(2)	?	R.	..	..	..	..	..	..	..	308·0	307·0	..	..	..	..	..	..	..	..	..	..
41	?	R.	..	..	..	377·2	366·9	352·9	..	..	..	..	..	..	..	..	..	..	..	..	..
42	?	L.	..	..	..	..	..	..	..	327·0	321·8	..	..	..	..	..	..	..	..	..	..
43	♀	R.	..	..	..	394·7	383·3	366·9	..	..	..	..	..	..	..	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maxi-mum.	Ob-lique.	Neck.	Maxi-mum.	Ex-cluding spine.	Centre to centre	Maxi-mum.	Maxi-mum.	Ob-lique.	Maxi-mum.	Centre to centre.	Maxi-mum.	Ex-cluding styloid.	Maxi-mum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
43	♀	L.	467·6	463·5	..	392·0	380·0	365·0	..	..	..	..	..	..	..	..	..	..	..	..	..
49	♀	R.	432·3	427·0	..	352·3	343·0	329·8	..	..	..	..	..	..	..	..	83·1	119·0	..	..	..
		L.	..	..	..	352·8	343·8	331·3	..	..	..	238·3	225·3	..	..	..	..	..	..	..	..
50	♂	R.	441·0	435·0	..	366·0	358·0	344·6	..	319·2	..	..	..	..	..	142·4	94·8	116·4	..	..	..
		L.	443·2	438·6	..	370·1	362·4	348·0	..	314·8	313·0	249·5	235·0	..	..	..	..	..	..	..	..
51	?	R	418·0	417·4	..	..	..	..	..	305·3	303·1	244·5	230·1	..	..	147·2	..	..	..	..	..
		L.	..		..	358·8	350·9	336·3	..	300·3	..	..	..	..	..	143·2	..	..	..	..	..
52	♂	R.L.	..	..	..	..	..	*l* 353·2	..	*r* 313·2	*r* 311·8	*r* 244·2	*r* 231·4	..	..	..	..	..	..	..	..
53	♂	R.	458·5	457·0	..	384·2	374·8	359·2	371·0	320·5	312·3	252·0	239·0	274·8	269·5	156·3	..	..	156·1	107·8	107·0
		L.	..	..	..	388·4	378·0	363·3	374·0	322·3	315·0	252·0	237·8	274·0	269·0	154·0	..	..	..	108·5	106 1
54	♀	R.	..	..	..	..	..	..	..	..	..	..	..	273·0	267·0	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	..	..	269·2	263·0	..	..	..	..	..	..
59	?	R.	..	..	..	360·3	352·7	339·6	..	..	..	..	..	..	..	..	105·0	106·0	..	..	..
		L.	..	..	..	..	..	343·4	..	..	..	..	..	..	..	..	..	..	..	..	..
63	♀	R.L.	..	..	..	..	..	..	..	..	..	*l* 244·0	*l* 230·0	..	*l* 255·0	*r* 169·2	..	..	..	..	..
64	♀	R.L.	..	..	..	..	..	..	..	*l* 293·0	..	..	..	..	..	*l* 139·0	..	..	*r* 135·3	*r* 92·5	*r* 93·2
71	?	R.	..	..	..	..	..	..	..	..	..	..	..	263·2	261·0	..	..	..	..	..	..
71B	?	R.	435·5	432·1	68·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
74	?	L.	..	..	..	350·0	342·7	330·3	..	..	..	..	..	..	..	..	..	..	..	..	..
80	?	L.	..	..	..	..	..	..	..	261·2	259·8	..	..	..	..	132·8	..	..	..	..	..
81	♀	R.	409·7	404·1	64·6	..	..	..	..	286·8	283·0	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	333·2	324·0	312·2	..	283·2	..	..	..	..	..	..	..	..	..	..	..
85	?	L.	..	..	..	..	..	..	..	..	..	..	210·3	..	..	..	..	..	..	..	..
86	♀	R.	..	..	..	..	..	..	..	..	..	226·2	214·3	..	..	136·5	..	..	..	..	..
		L.	..	..	..	..	..	..	..	291·2	288·0	212·0	..	..	..	..	..	..	..	..	..
87	?	R.	..	..	..	..	..	..	..	306·3	301·3	..	..	..	..	..	..	..	..	..	..
88	?	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	142·5	..	..	..	..	..
94	♀	R.	430·2	426·8	..	358·7	352·3	349·2	..	294·5	293·0	..	..	..	..	132·2	..	..	..	..	..
		L.	..	..	..	357·9	350·2	338·5	..	289·0	..	..	..	245·2	241·8	..	..	..	..	..	..
108*a*	?	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	134·0	..	..	..	..	..
109	♀	R.	..	..	..	368·3	357·2	341·8	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	371·8	362·0	346 2	..	..	..	..	..	..	..	..	..	..	..	..	..
113A	♂	R.	..	..	..	374·0	363·5	348·9	..	..	..	253·2	238·0	266·3	262·2	..	..	..	..	..	..
		L.	..	..	..	..	..	..	351·0	317·0	314·4	..	240·0	265·0	..	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
113B	?	R.	..	..	..	..	..	..	..	..	..	218·0	207·3	..	..	..	81·5	118·8	..	..	..
114	♀	R.	..	..	..	394·5	384·6	372·6	..	..	..	..	..	..	..	..	110·0	103·9	..	..	..
		L.	..	..	..	394·2	384·3	372·7	..	..	..	252·2	238·0	271·0	268·0	..	..	..	..	..	..
115	♀	R.	..	..	..	339·2	332·2	318·4	..	..	..	..	..	..	..	..	101·2	108·2	..	..	..
		L.	401·0	399·0	..	..	..	322·9	..	..	..	..	..	241·2	237·0	..	..	..	..	..	..
116	?	R.	441·3	437·5	66·6	..	..	..	..	..	..	..	..	267·0	260·6	?137·8	..	..	..	..	..
119*a*	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	112·4	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	..	..	..	..	113·0	..	..	..	..	..
121	♀	R.	..	..	..	367·2	359·0	344·6	..	309·6	304·2	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	369·8	361·5	347·5	..	..	..	..	..	259·6	256·3	..	..	..	..	..	..
124	?	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	136·9	..	..	..	..	..
128	?	L.	..	..	..	..	..	372·0	..	..	..	..	..	..	..	..	..	..	..	..	..
143	?	R.	..	..	..	377·0	367·8	354·0	..	..	..	..	..	..	..	..	..	..	..	..	..
148	♀	R.	..	..	..	365·0	356·8	343·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	346·0	..	..	..	..	..	..	..	..	..	..	..	..	..
176B	?	L.	440·3	437·0	63·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
182	?	L.	463·4	460·8	71·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
183	?	R.	..	..	..	..	..	392·5	..	..	..	..	..	..	..	..	..	..	..	..	..
197	♂	R. L.	*r* 443·2	*r* 442·8	*r* 69·8	..	..	*l* 376·8	..	..	..	..	..	..	..	..	..	..	..	..	..
204	?	R.	435·6	434·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	444·3	442·2	67·0	..	..	372·0	..	..	..	..	..	..	..	..	..	..	..	..	..
210	?	R.	..	..	..	..	..	316·0	..	..	..	..	..	..	..	..	..	..	..	..	..
214	?	R.	..	..	..	390·2	381·0	368·8	..	..	..	..	..	..	..	..	..	..	..	..	..
215	?	L.	..	..	..	411·0	401·2	387·0	..	..	..	..	..	..	..	..	..	..	..	..	..
221	?	R.	..	..	..	..	..	..	..	301·3	297·5	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	296·3	291·5	..	..	..	..	..	..	..	..	..	..
225	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	135·3	..	..	..	..	..
226	?	R.	407·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
232	♂	R.	444·5	440·2	..	379·0	370·0	354·8	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	381·6	372·3	357·3	..	..	..	..	..	..	..	..	..	..	..	..	..
236	?	R.	431·3	428·0	67·0	..	..	..	..	306·0	304·3	249·8	238·0	..	..	..	..	..	..	..	..
		L.	..	..	..	369·5	362·3	349·0	..	308·2	..	..	..	..	..	..	..	..	..	..	..
240	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	147·8	..	..	..	..	..
251	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	139·0	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
255	♂	R.	379·0	373·3	..	407·0	395·4	382·4	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	377·0	374·0	..	..	..	..	395·4	..	..	..	..	..	..	..	..	..	..	..	..
256	?	R.L.	*l* 433·4	*l* 430·8	..	*r* 375·0	*r* 366·0	*r* 351·0	..	..	..	*l* 242·2	*l* 229·8	..	..	*l* 147·3	..	..	..	..	..
260	?	R.	..	..	..	..	..	..	417·0	..	..	..	..	..	..	..	..	..	..	..	..
262	?	R.L.	..	..	..	..	..	..	..	..	..	*l* 256·0	*l* 243·5	..	..	156·2	..	..	..	..	..
264	?	R.	..	..	..	..	..	348·0	..	..	..	..	..	..	..	..	..	..	..	..	..
266	?	L.	..	..	..	..	..	377·3	..	..	..	..	..	..	..	..	..	..	..	..	..
269	?	R.	444·0	438·0	..	374·0	366·0	352·9	..	..	..	..	..	..	..	140·0	..	..	..	..	..
		L.	..	..	..	373·8	365·2	353·0	363·2	..	..	..	..	..	..	140·8	..	..	..	..	..
276	?	L.	..	..	..	..	..	..	..	312·4	309·2	..	..	..	..	..	..	..	..	..	..
277	?	L.	..	..	..	414·0	400·9	385·0	..	..	..	..	..	..	..	..	..	..	..	..	..
279	?	R.L.	..	..	..	..	..	..	..	..	..	..	..	*r* 242·0	*r* 237·8	*l* 144·3	..	..	..	..	..
282	♀	R.	428·8	423·0	65·5	362·0	355·0	341·0	..	..	..	..	..	..	..	..	..	..	..	..	..
283A	?	R.	419·5	406·2	60·6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
283B	?	R.	492·3	486·2	..	415·3	404·0	391·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	487·5	486·3	..	..	..	..	..	345·3	330·0	..	..	..	..	..	..	..	..	..	..
283C	?	R.	..	..	..	413·8	403·7	387·5	..	343·8	332·5	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	412·0	401·3	386·3	..	..	..	..	..	..	..	..	..	..	..	..	..
284	♂	R.	452·5	..	..	377·1	366·3	351·2	..	..	..	..	..	291·5	282·4	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	322·1	318·0	..	..	286·5	280·5	..	..	..	..	..	..
294	♂	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	144·8	..	..	..	..	..
296	♀	—	..	..	..	..	..	..	..	..	..	..	..	..	..	..	112·0	118·2	..	..	..
299	?	L.	..	..	..	..	..	..	..	..	..	263·0	249·3	..	..	..	..	..	..	..	..
300	?	L.	..	..	..	..	..	..	..	330·2	329·8	..	..	..	..	..	..	..	..	..	..
303	?	L.	..	..	..	..	..	..	..	333·0	..	..	..	..	..	..	..	..	..	..	..
305	♀	R.	440·1	436·3	72·1	372·0	362·1	349·0	..	..	..	238·0	223·2	..	..	153·2	102·1	110·5	..	..	..
		L.	443·3	441·2	..	370·0	360·2	348·0	..	..	..	..	..	..	..	..	..	..	..	..	..
308	♂	R.	..	..	..	..	..	..	..	..	..	..	276·0	..	..	..	..	..	..	..	..
309	♀	R.L.	*r* 433·0	*r* 430·0	*r* 68·0	..	..	..	*r* 327·0	..	..	*l* 216·3	*l* 204·0	*l* 238·0	*l* 234·0	*r* 132·3	..	..	..	..	..
314	?	R.L.	..	..	..	*r* 334·5	*r* 328·0	*r* 315·0	..	..	..	..	..	*l* 242·4	*l* 236·7	..	..	..	..	..	..
315	♂	R.	..	..	..	..	..	..	..	318·0	315·0	..	..	..	..	136·5	..	..	..	..	..
		L.	415·4	412·8	..	..	..	323·0	..	316·8	311·8	..	..	..	257·0	143·2	..	..	..	..	..
316A	?	L.	428·5	..	..	..	..	..	362·9	..	..	..	..	..	..	..	102·5	108·9	..	..	..
316B	?	L.	..	..	..	346·0	338·2	327·0	..	..	..	..	..	..	..	..	..	..	..	..	..

GENLRAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
318	♂	R.	..	..	..	377·5	368·4	355·5	364·7	329·0	327·0	259·2	244·8	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	323·0	321·0	..	..	..	..	151·2	..	..	..	..	..
324	?	L.	..	..	..	..	..	336·2	..	..	..	..	..	..	..	..	..	..	..	..	..
330	♀	R.	408·2	406·4	..	348·0	341·0	328·6	.	292·3	291·8	..	..	..	..	..	..	..	..	..	..
		L.	409·0	406·0	..	351·0	343·8	332·0	..	..	..	..	..	..	..	..	..	..	..	..	..
331	♂	R.	..	..	..	395·0	386·6	373·9	381·7	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	398·0	389·8	375·8	..	..	..	..	..	..	..	..	..	..	..	..	..
341	?	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	139·8	..	..	..	..	..
342	♀	L.	..	..	..	..	..	..	..	298·3	297·0	..	..	..	..	..	..	..	..	..	..
343	♂	R.L.	r456·2	..	..	..	..	..	..	r317·1	r314·8	l240·2	l226·0	..	..	..	..	..	..	r92·5	r103·8
348	♀	R.	413·0	410·2	64·1	..	.	335·5	..	..	..	..	..	..	..	..	87·0	106·5	..	..	..
		L.	412·3	410·0	..	353·2	345·0	332·3	..	..	..	..	..	..	..	..	..	..	..	..	..
358	♂	R.	451·8	448·2	..	386·2	378·0	364·0	374·5	312·3	308·8	..	..	266·0	262·3	..	87·2	106·0	144·2	93·2	104·0
		L.	448·8	447·1	70·0	386·2	377·8	366·3	..	305·8	302·6	..	..	265·0	262·3	..	..	..	..	..	..
363	♂	R.	..	..	..	..	..	..	..	333·7	331·6	264·5	249·2	287·8	282·0	167·5	98·2	109·0	..	..	..
		L.	462·5	458·0	..	386·0	373·6	359·0	..	..	..	266·0	249·2	..	..	..	..	..	..	..	..
370 ?	?	L.	..	..	..	..	..	..	..	..	..	257·4	243·1	..	..	..	..	..	..	..	..
377	♀	R.	404·0	401·9	65·2	..	..	..	369 8	..	..	..	..	..	..	..	..	..	..	..	..
381	♂	R.	459·8	458·9	..	396·0	386·0	371·3	..	..	..	..	..	..	..	..	..	..	..	..	..
382	♂	R.	465·3	461·0	..	382·0	371·4	356·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	464·0	461·3	74·7	384·0	374·8	359·0	..	..	..	..	..	..	..	147·3	..	..	..	..	..
383	♂	R.L.	l450·0	l455·0	..	..	..	l375·2	r382·8	l321·6	l320·1	..	..	..	..	..	..	..	..	..	..
385	♂	R.	477·2	474·3	..	..	..	..	..	..	..	..	..	280·8	277·0	..	..	..	..	..	..
386	?	R.	..	..	..	392·0	382·0	368·0	..	..	..	..	..	..	..	..	..	..	..	..	..
388	?	R.L.	r420·0	r413·8	r64·0	l360·0	l350·8	l338·4	..	..	..	..	..	..	..	..	..	..	..	..	..
391	♀	R.	415·2	..	..	..	345·2	330·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	416·1	414·0	67·1	358·5	350·0	354·6	..	..	..	..	..	..	..	..	..	..	..	..	..
401	?	R.	..	..	..	..	..	..	..	..	..	265·4	252·3	..	..	169·2	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	..	245·0	278·3	275·5	..	..	..	..	..	..
402	♀	R.	425·5	424·0	74·0	347·0	338·8	327·0	..	291·4	289·0	..	..	250·5	246·8	..	103·0	106·7	..	..	..
		L.	426·5	425·4	..	349·8	339·8	326·5	..	289·8	285·4	228·5	216·2	248·1	244·8	..	..	..	..	..	..
403 ?	?	R.	..	..	..	..	..	..	..	300·0	297·0	..	..	..	..	..	..	..	..	..	..
412	?	R.	..	..	..	..	..	..	377·0	..	..	286·5	..	..	..	..	..	..	..	..	..
417	?	R.L.	l455·0	l451·2	..	l377·3	l370·0	l356·0	r344·3	..	..	..	..	..	..	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
422	?	L.	430·5	426·5	67·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
425	♂	R.	..	..	..	354·0	345·0	329·5	343·0	320·0	317·0	..	..	..	..	142·3	..	..	..	..	..
		L.	..	..	..	354·3	345·2	331·0	346·5	314·3	310·2	..	..	..	..	..	..	..	..	..	..
428	?	R.	..	..	..	..	338·0	324·0	..	..	..	..	..	..	..	124·9	..	..	..	..	..
		L.	..	..	..	347·5	340·6	326·8	..	..	..	..	..	..	..	..	..	..	..	..	..
431 ?	?	R.	..	..	..	388·5	379·0	365·0	..	..	..	..	..	..	..	..	..	..	..	..	..
434	♀	R.L.	*r* 436·2	*r* 434·0	..	*l* 382·8	..	..	..	*l* 306·3	*l* 303·0	..	..	*l* 262·3	*l* 255·8	..	108 8	110·2	..	..	..
437	♂	R.	471·0	464·0	..	410·8	401·0	384·0	391·8	338·1	332·4	268·3	254·5	..	..	..	106·5	114·0	..	..	..
		L.	476·0	470·4	..	410·3	401·2	385·1	392·4	335·5	333·0	..	..	..	..	..	..	..	..	..	..
441	♂	R.	474·8	..	..	..	..	..	..	340·1	335·3	..	..	..	..	..	..	..	..	..	..
442	♂	R.L.	*r* 416·3	*r* 413·2	..	*l* 353·2	*l* 342·7	*l* 329·8	..	?*r* 288·0	?*r* 284·1	..	..	*r* 260·3	*r* 256·3	*r* 145·8	..	..	..	..	..
470	♀	R.	431·2	427·5	..	364·0	355·0	339·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	432·0	429·3	..	..	..	337·2	..	..	..	..	..	..	..	..	..	..	..	..	..
473	?	R.L.	*r* 441·0	..	..	..	..	..	..	..	..	..	..	*l* 267·2	*l* 262·4	..	..	..	..	..	..
480	?	R.	..	..	..	..	..	..	339·0	..	..	..	..	..	..	..	..	..	..	..	..
502	♀	R.L.	..	..	..	..	..	..	..	*r* 309·7	*r* 305·0	*l* 243·1	*l* 230·2	..	..	..	..	..	..	..	..
507	♀	R.	..	..	..	..	..	334·8	..	301·3	300·9 (−)*	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	354·0	345·8	333·0	..	..	..	..	..	..	..	..	..	..	..	..	..
510	?	R.	..	..	..	..	..	..	..	..	..	229·0	217·0	246·7	242·0	..	..	..	..	..	..
511	?	R.	439·2	430·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
512	?	L.	390·0	387·0	..	331·2	322·4	308·4	..	..	..	..	..	..	..	..	..	..	..	..	..
519*b*	♀	R.	468·8	466·9	72·3	388·0	380·0	365·9	375·0	..	..	..	..	..	..	..	..	..	..	..	..
		L.	463·7	462·5	..	388·3	379·4	366·0	372·8	320·2	317·3	259·7	247·0	278 2	273·5	..	..	..	..	..	..
522	?	L.	..	..	..	..	..	..	362·3	..	..	..	..	..	..	..	..	..	..	..	..
523	♀	L.	..	..	..	..	..	..	371·0	..	..	..	..	..	..	..	..	..	..	..	..
525	?	R.	..	..	..	..	..	..	..	311·2	307·2	..	..	..	..	..	..	..	..	..	..
526	♂	R.	436·4	433·8	..	..	..	336·8	..	323·0	320·1	242·0	238·4	..	..	144·2	..	..	..	98·9	102·5
		L.	441·2	437·2	71·6	361·5	351·7	338·3	345·0	319·5	317·4	245·0	232·0	263·2	258·4	..	..	..	..	..	..
527	♀	R.	..	..	..	373·0	365·2	350·3	..	..	..	..	..	..	..	..	94·7	118·0	..	..	..
		L.	433·7	427·2	..	374·8	364·8	351·5	..	..	..	..	..	..	..	..	..	..	..	..	..
529	?	R.L.	..	..	..	..	..	..	..	..	..	..	*r* 218·5	..	..	*l* 133·0	..	..	..	..	..
530	♂	R.	425·0	419·8	69·0	369·0	360·0	345·5	..	312·3	306·5	..	..	..	..	..	..	..	..	97·0	115·0
		L.	426·2	423·3	70·0	370·3	361·4	348·0	..	309 0	307·0	252·3	237·7	277·3	273·0	..	..	..	..	98 9	113·0

* The sign (−) indicates that the bone sloped outwards instead of inwards when the trochlea and capitellum were placed on a horizontal plane.

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
531	♀	R.L.	*r*439·5	*r*434·5	*r*67·1	*l*362·6	*l*354·6	*l*343·5	..	*l*292·4	*l*289·6	..	..	..	..	*l*148·5	..	..	..	..	..
533	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	118·9	..	..	..	..	..
534	♂	R.L.	*l*421·7	..	..	*l*352·8	*l*343·7	*l*330·2	..	*r*299·8	*r*295·0	..	..	..	..	*r*143·0	..	..	..	..	..
535	♀	R.	..	..	..	..	..	..	..	..	..	236·0	224·0	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	229·3	219·0	..	..	..	..	..	..	..	..
537	♀	R.	421·0	416·7	62·5	345·8	336·3	323·6	334·5	..	..	..	..	..	..	..	..	..	..	..	..
		L.	424·8	420·8	60·7	349·3	340·0	328·2	..	..	..	..	..	..	..	..	..	..	..	..	..
538	♀	L.	..	..	..	351·6	344·0	332·0	..	..	..	..	..	..	..	..	..	..	..	..	..
540	?	R.	..	..	..	..	346·0	332·6	..	..	..	..	..	..	..	..	..	..	..	..	..
541	♀	R.	413·2	408·8	61·1	..	..	..	..	295·0	292·8	228·3	215·6	..	..	142·0	..	..	..	..	..
		L.	409·8	408·3	..	347·6	338·0	323·0	341·0	291·5	289·5	225·6	213·0	..	247·2	..	..	..	..	..	..
542	♀	R.	455·6	450·2	74·6	367·8	360·2	347·0	..	..	..	234·4	223·0	..	251·4	133·2	..	..	..	..	..
		L.	457·8	454·0	..	368·0	360·2	347·0	..	295·8	289·7	233·2	222·3	..	..	139·0	..	..	..	..	..
544	♂	R.	458·0	457·0	..	384·0	375·3	361·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	461·5	459·0	..	..	..	..	..	323·0	317·8	..	..	..	..	..	..	..	..	..	..
546	♀	R.	416·8	410·0	..	347·2	336·8	323·3	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	417·8	411·4	..	344·1	335·0	322·1	335·2	..	..	..	..	..	..	..	..	..	..	..	..
548	?	R.	..	..	..	346·0	336·1	323·6	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	345·2	336·1	323·9	..	..	..	..	..	..	..	..	..	..	..	..	..
550	♀	R.	449·2	444·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	442·0	436·4	..	359·8	351·0	338·9	351·2	297·5	297·5	..	..	..	..	..	..	..	..	..	..
551	♀	R.	..	..	..	..	..	..	..	306·6	301·2	237·0	225·0	..	..	138·0	..	..	..	..	..
		L.	..	..	..	..	..	..	..	304·4	301·5	234·2	221·3	..	..	..	..	..	..	..	..
552	?	R.	..	..	..	..	..	339·7	..	..	..	..	..	..	..	..	..	..	..	..	..
553	?	L.	..	..	..	..	..	..	..	..	..	240·3	226·2	..	..	..	..	..	..	..	..
556	♀	R.	..	..	..	..	..	..	..	300·2	297·0	..	..	..	..	..	..	..	..	..	..
		L.	427·0	421·3	64·6	..	..	..	..	295·3	292·0	..	..	..	..	..	..	..	..	..	..
563	?	L.	..	..	..	..	..	350·3	..	..	..	..	..	..	..	..	..	..	..	..	..
570	♀	R.	407·7	402·8	..	353·0	344·4	331·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	412·3	407·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
575	♂	R.	464·0	..	..	411·8	402·6	387·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	271·5	257·2	297·0	289·0	..	..	..	..	..	..
576	♀	R.	401·7	396·0	63·5	334·2	325·0	312·0	..	279·5	277·2	218·0	207·0	..	..	136·0	..	..	..	..	..
		L.	400·2	395·8	..	334·3	325·5	313·3	..	274·0	..	211·2	199·8	235·8	231·3	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maxi-mum.	Ob-lique.	Neck.	Maxi-mum.	Ex-cluding spine.	Centre to centre.	Maxi-mum.	Maxi-mum.	Ob-lique.	Maxi-mum.	Centre to centre.	Maxi-mum.	Ex-cluding styloid.	Maxi-mum.	Length.	Breadth	Length.	Breadth	Infra spinous length.
577	?	R.	434·6	430·4	65·4	..	..	..	..	..	..	228·0	216·0	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	340·0	..	297·5	294·5	225·8	214·0	..	..	131·4	..	..	..	..	..
578	?	R.	..	..	..	..	..	332·0	..	..	..	..	..	..	..	136·0	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	..	..	..	..	143·2	..	..	..	..	..
583	♂	R.	455·0	448·3	..	373·0	362·8	349·3	..	..	..	251·8	237·8	..	..	..	..	..	..	..	..
586	♀	R.L.	r422·8	r418·0	r 65·8	l 354·0	l 346·0	l 333·0	..	..	..	..	..	..	..	..	..	..	..	..	..
588	?	R.	..	..	..	..	..	..	..	311·3	308·0	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	393·0	384·7	369·0	..	310·3	..	236·0	223·2	259·7	254·0	..	..	..	..	..	..
590	?	R.	..	..	..	412·5	401·2	386·5	..	331·2	..	256·0	244·0	..	..	..	..	..	..	..	..
593	♀	R.	..	..	..	366·0	358·0	342·0	..	..	..	234·0	220·5	..	..	..	..	..	..	..	..
		L.	..	..	..	363·2	354·3	339·0	..	295·2	291·2	..	..	..	..	..	..	..	..	..	..
594	♂	R.	457·5	454·8	70·6	389 5	379·0	364·0	378·0	335·0	333·0	..	..	283·2	276·8	..	92·8	111·4	..	..	..
		L.	459·0	451·4	69·5	394·0	384·0	369·5	..	..	..	..	..	..	..	..	..	..	..	..	..
597	?	L.	432·0	428·0	69·3	363·0	352·0	340·0	349·8	..	..	..	..	..	..	..	..	..	..	..	..
610	♀	R.	..	..	..	..	346·8	334·0	..	298·4	297·0	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	363·0	354·3	339·5	..	..	..	..	..	..	..	..	..	..	..	..	..
612	?	R.	..	..	..	353·0	345·0	330·5	..	..	..	..	..	..	..	..	..	..	..	..	..
617	♀	R.	..	..	..	377·2	367·0	352·0	..	321·3	318·0	257·0	244·0	..	..	..	103·3	115·2	..	..	..
		L.	..	..	..	376·8	368·4	355·4	..	..	..	..	..	..	..	..	..	..	..	..	..
618	♀	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	125·6	..	..	..	..	..
620	♂	R.L.	..	..	..	..	..	..	..	r319·3	r311·2	..	..	..	..	l 153·2	102·0	110·3	..	..	..
625	♀	R.	411·2	405·8	66·0	345·2	337·0	322·7	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	407·0	404·0	..	..	..	321·0	..	..	..	..	..	..	..	..	..	..	..	..	..
627	♂	R.	..	..	..	374·0	364·4	350·0	..	..	..	..	..	..	..	..	96·8	110·3	..	..	..
		L.	447·0	443·2	69·5	378·3	369·0	354·0	..	..	..	..	..	..	..	..	..	..	..	..	..
632	?	R.L.	..	..	..	..	..	..	..	l 302·0	l 298·0	r241·6	r228·8	r263·7	r257·0	..	..	..	..	..	..
633	♂	R.	..	..	..	414·0	404·2	388·3	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	481·4	477·0	78·3	411·0	400·6	386·3	..	..	..	..	..	..	..	..	..	..	..	..	..
634	♀	R.	416·4	412·0	62·2	347·2	339·0	326·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	417·6	414·2	..	349·0	340·3	329·0	..	..	..	..	..	..	..	146·0	..	..	..	..	..
635	♀	R.	423·0	419·0	66·2	358·0	349·0	335·3	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	424·0	421·8	..	362·0	353·0	339·0	..	..	..	..	..	..	..	..	..	..	..	..	..
636	♂	R.	433·0	429·0	..	376·0	366·7	351·3	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	438·2	..	..	378·0	367·2	353·1	..	..	..	..	..	..	..	..	..	..	..	..	..

General Graves.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
637	♀	R.L.	*r* 449·5	*r* 447·4	..	..	..	..	..	..	..	..	..	*l* 254·0	*l* 251·3	..	103·9	105·2	..	..	..
639	?	L.	423·2	416·0	67·6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
643	♀	R.L.	..	..	..	..	..	..	..	*r* 304·0	*r* 298·2	*l* 252·2	*l* 246·4	..	..	..	..	..	..	..	..
646	♂	R.L.	*l* 463·0	*l* 462·1	*l* 74·5	*l* 393·0	*l* 383·3	*l* 368·3	..	*l* 324·2	*l* 322·0	*r* 265·7	*r* 251·0	..	..	..	..	..	..	..	..
647	♀	R.	407·3	405·5	63·8	334·0	325·2	311·6	..	289·2	287·0	..	..	..	..	..	..	..	..	..	..
		L.	408·3	..	..	..	..	..	..	..	..	..	..	..	..	137·6	..	..	..	..	..
650	?	R.L.	..	..	..	*r* 382·4	*r* 376·0	*r* 363·4	..	*l* 330·3	*l* 329·8	..	..	..	..	..	..	..	..	..	..
652	♀	R.	..	..	..	349·5	341·7	329·0	..	..	..	231·2	220·2	..	..	..	..	..	..	..	..
		L.	..	..	..	351·7	342·0	331·0	..	298·1	296·0	..	..	254·1	248·4	..	..	..	..	..	..
658	♀	R.	449·0	442·0	70·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	447·6	444·2	..	373·0	364·5	352·0	362·1	..	..	..	..	..	..	..	..	..	..	..	..
660	♂	R.	443·0	440·5	..	386·0	377·1	362·0	..	327·0	325·0	..	..	280·1	274·3	..	..	..	..	..	..
		L.	445·0	443·0	..	..	..	..	..	322·4	319·9	..	..	..	..	..	..	..	..	..	..
661	?	R.L.	*l* 406·2	*l* 400·2	..	..	..	..	..	..	..	..	..	..	..	*r* 136·3	..	..	..	..	..
662	♀	—	..	..	..	..	..	..	..	..	..	..	..	..	..	..	80·2	114·6	..	..	..
664	♀	R.	..	..	..	..	..	..	..	340·2	334·3	..	..	?263·8	?261·8	..	..	..	..	..	..
		L.	..	..	..	390·8	381·2	366·0	..	341·5	331·5	..	..	285·0	284·0	154·8	..	..	..	..	..
667	?	R.	..	..	..	360·2	351·2	337·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	427·4	424·0	67·1	360·3	351·2	338·2	343·3	291·7	290·1	..	..	..	..	..	..	..	..	..	..
668	♂	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	143·1	..	..	..	..	..
674	?	L.	..	..	..	..	..	..	..	288·2	287·8	..	..	..	..	..	..	..	..	..	..
681	?	R.	..	..	..	..	..	..	..	281·0	276·5	..	..	..	..	137·5	..	..	..	..	..
683	♂	R.L.	..	..	..	..	..	..	..	..	..	*r* 286·0	*r* 270·0	..	*r* 303·2	*l* 150·7	..	..	..	..	..
687	?	R.	..	..	..	401·0	392·0	378·2	..	..	..	..	..	..	..	..	..	..	..	..	..
690	♀	R.	443·0	439·0	..	364·8	356·0	343·0	351·0	..	..	..	..	..	..	..	..	..	..	..	..
691	?	R.	..	..	..	368·0	357·6	339·8	352·8	..	..	..	..	..	..	..	..	..	..	..	..
692	♀	R.	..	..	..	346·2	338·0	324·4	..	..	..	..	..	..	..	..	84·0	111·0	..	..	..
		L.	409·8	408·0	..	345·0	337·0	324·3	..	..	..	..	..	..	..	..	..	..	..	..	..
693	♀	R.	..	..	..	..	..	314·8	..	296·4	292·0	..	..	..	237·0	..	..	..	..	..	..
		L.	..	..	..	337·3	326·7	315·0	..	..	..	218·0	204·9	..	232·3	..	..	..	..	..	..
696	♀	R.	449·3	445·0	..	..	..	..	374·3	312·0	307·0	245·0	233·5	265·2	261·0	145·8	..	..	..	..	..
		L.	453·3	451·0	..	376·5	364·8	352·3	..	306·2	299·3	240·4	229·8	..	..	..	..	..	..	..	..
697	♂	R.	434·0	433·5	..	371·8	362·2	349·2	..	319·0	310·4	242·3	230·4	..	..	140·9	..	..	..	..	..
		L.	434·0	432·0	72·7	372·0	362·8	349·0	..	..	..	237·3	223·8	..	..	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
698	?	L.	..	..	..	..	..	..	337·3	..	..	..	..	..	..	..	..	..	..	..	..
701	♂	R.	446·5	440·6	..	373·2	363·2	349·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	445·6	443·0	75·3	373·3	363·8	348·4	..	..	..	247·7	232·9	265·3	262·4	..	..	..	..	..	..
706	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	153·6	..	..	..	..	..
707	♂	R.	488·6	484·8	..	406·5	397·3	382·5	..	..	..	261·1	247·4	278·3	274·2	..	..	..	..	..	..
		L.	..	..	..	408·2	399·0	386·0	395·3	..	..	..	..	..	..	..	..	..	..	..	..
710	♀	R.	..	..	..	379·0	369·4	354·5	361·2	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	376·8	367·0	353·0	357·0	..	..	238·0	226·2	..	..	..	..	..	..	..	..
711	♀	R.	..	..	..	..	..	..	..	292·0	282·0	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	285·2	..	..	..	..	..	..	..	..	..	..	..
712	♀	R.	442·0	434·5	..	383·5	374·6	362·4	369·4	304·5	300·8	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	386·3	379·4	366·9	..	299·8	297·5	..	..	..	..	..	..	..	..	..	..
716	♀	R.	388·0	386·0	62·9	321·0	312·3	297·3	309·3	278·0	272·5	..	..	..	..	130·0	..	..	..	..	..
		L.	385·3	383·5	66·9	..	..	..	..	270·3	268·0	..	..	233·2	228·0	137·0	..	..	..	..	..
717	♀	R.	413·2	411·1	67·1	339·3	332·0	317·2	..	287·0	286·0	..	217·0	252·9	248·7	130·4	91·3	104·0	..	..	..
		L.	418·3	414·0	65·9	..	..	..	..	283·0	282·1	230·0	216·0	252·0	246·0	134·7	..	..	..	..	..
718	♀	R.L.	*l* 435·3	*l* 433·2	..	..	..	..	*r* 353·0	*l* 311·3	*l* 308·5	*l* 245·0	*l* 230·0	..	*r* 262·8	*r* 142·0	86·4	106·8	..	..	..
722	?	R.	437·5	436·8	..	..	..	..	..	315·0	313·0	..	..	..	..	151·3	..	..	..	..	..
		L.	..	..	..	373·0	363·0	348·1	..	313·0	309·3	..	..	..	..	..	..	..	..	..	..
724	♀	R.	442·0	439·0	..	358·0	349·0	335·3	..	..	..	239·0	226·4	..	..	..	..	..	..	..	..
		L.	449·0	439·0	66·0	363·8	355·2	341·6	356·4	..	..	..	..	..	..	..	..	..	..	..	..
727	?	R.	427·0	423·0	65·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
728	♀	R.	431·3	417·5	..	364·5	356·5	341·8	..	306·2	302·0	236·8	224·5	..	..	146·5	..	..	..	..	..
		L.	429·0	422·3	66·5	..	..	..	..	301·0	298·2	..	..	..	..	..	..	..	..	..	..
729	?	R.	475·0	472·0	..	374·2	363·7	345·5	..	329·0	321·2	255·5	241·3	..	..	153·2	..	..	..	..	..
		L.	475·4	470·4	..	372·0	361·6	345·0	356·0	327·0	320·6	255·0	242·0	275·5	272·3	161·3	..	..	..	..	..
730	♀	R.L.	*l* 445·4	*l* 443·0	*l* 69·7	*r* 383·0	*r* 374·8	*r* 360·2	..	*r* 318·3	*r* 316·0	*l* 244·2	*l* 230·6	..	..	*r* 141·6	105·3	117·4	..	..	..
731	♀	R.	..	..	..	391·0	380·4	367·0	378·0	..	..	..	..	..	..	..	105·2	119·1	..	..	..
		L.	..	..	..	..	..	..	377·0	308·4	306·0	..	..	279·4	275·1	..	..	..	..	..	..
733	♀	R.L.	..	..	..	*l* 390·2	*l* 381·0	*l* 367·0	..	..	..	..	*r* 241·3	..	..	..	..	..	..	..	..
736	?	R.L.	..	..	..	*r* 327·5	*r* 317·6	*r* 304·4	..	..	..	*l* 214·2	*l* 203·1	..	..	..	..	..	..	..	..
740	♀	R.	..	..	..	..	..	..	..	298·2	297·0	237·4	225·3	259·2	254·3	137·4	..	..	..	..	..
		L.	..	..	..	375·3	368·3	354·8	..	292·0	291·2	230·2	218·2	..	..	138·0	..	..	..	..	..
741	?	L.	426·0	423·0	63·1	354·0	346·0	331·8	..	..	..	243·7	231·2	..	..	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
743	?	L.	..	..	..	359·2	352·3	336·8	..	..	..	..	..	..	..	..	..	..	..	..	..
744	?	R.L.	*l* 437·0	*l* 434·3	..	*r* 373·0	*r* 364·3	*r* 350·5	..	..	..	..	..	..	..	..	..	..	..	..	..
746	?	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	160·0	..	..	..	..	..
748	♂	R.	441·2	438·0	69·8	372·3	364·1	349·0	..	316·0	314·3	256·2	242·3	275·0	273·7	154·0	87·2	102·0	..	..	..
		L.	438·0	436·2	70·5	375·2	368·0	352·3	..	314·8	312·7	..	..	..	..	151·1	..	..	..	..	..
749	♀	R.L.	..	..	..	*r* 333·7	*r* 323·0	*r* 309·0	*l* 312·0	..	..	..	..	..	..	..	..	..	..	..	..
751	♀	R.	397·4	395·0	60·4	338·0	331·2	319·0	..	297·5	293·4	224·0	212·4	243·0	237·4	137·0	..	..	..	..	..
		L.	..	..	..	340·0	332·0	320·0	..	290·3	285·8	221·5	210·0	242·0	237·0	..	..	..	..	..	..
751x	?	R.	..	..	..	..	..	..	..	..	..	..	..	266·8	261·5	..	..	..	..	..	..
		L.	430·2	426·5	..	..	..	..	..	300·2	299·6	240·0	227·2	261·0	254·0	..	..	..	..	..	..
753	♀	R.	444·2	440·1	68·4	361·2	353·0	338·2	..	..	..	..	..	..	..	..	87·0	102·0	..	..	..
		L.	442·0	438·0	70·1	359·0	351·5	337·0	..	306·1	305·3	236·6	222·3	..	..	147·2	..	..	..	..	..
754	♀	R.	454·0	450·8	..	369·0	362·0	348·0	..	..	..	..	..	..	..	..	87·0	110·5	..	..	..
		L.	455·0	452·6	..	375·0	366·5	352·3	359·5	307·0	303·2	..	..	..	..	140·0	..	..	..	97·2	108·3
756	?	R.	..	..	..	..	..	329·0	..	..	..	..	..	..	..	..	..	..	..	..	..
759	?	R.	..	..	..	..	..	..	353·4	..	..	..	..	..	..	..	..	..	..	..	..
765	?	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	152·1	..	..	..	..	..
800	?	R.	421·0	414·7	66·0	343·0	335·0	321·4	329·0	..	..	..	..	..	..	..	..	..	..	..	..
804	♀	R.	445·5	..	..	361·3	352·0	338·3	..	308·0	302·0	237·2	224·0	..	..	..	..	..	..	..	..
		L.	442·4	440·8	69·5	358·2	349·0	336·0	351·7	302·0	..	..	..	..	..	..	..	..	..	..	..
810A	?	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	94·2	107·1	..	..	..
819	?	L.	..	..	..	..	..	..	..	..	..	220·3	208·5	..	..	..	..	..	..	..	..
823	♂	R.	..	..	..	388·9	379·8	363·4	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	393·2	384·3	369·9	..	322·6	319·4	260·2	247·0	280·2	278·1	152·2	..	..	..	..	..
827	♀	R.	412·3	408·3	..	..	..	..	..	290·4	288·3	223·3	210·0	..	..	..	..	..	..	..	..
		L.	419·3	415·1	..	330·3	321·7	310·3	..	286·5	..	221·0	207·3	..	..	..	..	..	..	..	..
828	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	154·2	..	..	..	..	..
829	♀	R.	440·0	432·8	..	367·0	358·0	347·0	354·8	..	..	..	..	..	..	..	112·1	115·2	..	..	..
		L.	..	..	..	369·0	360·6	348·5	..	..	..	..	..	..	..	..	..	..	..	..	..
830	?	L.	..	..	..	..	..	..	..	..	..	252·7	240·3	..	..	..	..	..	..	..	..
832	♀	R.	398·0	393·2	..	327·7	318·9	307·3	..	282·9	282·1	219·4	209·0	..	233·7	141·2	97·4	104·0	..	..	..
		L.	397·0	394·0	..	327·0	319·2	307·8	..	277·0	276·8	219·3	209·2	..	..	..	..	..	..	..	..
833	?	R.	..	..	..	..	..	..	375·0	..	..	..	..	..	..	147·5	111·0	118·0	..	..	..
834	♀	R.L.	..	..	..	*l* 341·5	*l* 336·0	*l* 322·1	..	..	..	..	..	*r* 251·2	*r* 247·0	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
838	♂	R.L.	..	..	..	r389·0	r380·2	r365·0	..	l336·0	..	..	r242·3	..	..	..	..	..	..	..	..
840	♂	R.	493·2	491·5	..	..	..	..	..	362·4	360·8	..	..	..	..	173·4	90·3	112·2	..	..	..
841	♂	R.	443·7	441·8	72·4	369·0	359·0	345·0	356·8	..	..	..	..	..	..	..	..	..	..	..	..
		L.	447·0	444·5	71·9	367·2	355·0	341·4	..	..	..	..	..	..	..	..	..	..	..	..	..
842	♀	R.	..	..	..	..	..	..	..	..	..	..	..	259·4	254·0	136·0	..	..	..	..	..
		L.	..	..	..	..	..	..	..	304·0	301·7	229·8	217·4	254·0	250·0	..	..	..	..	..	..
843	♂	R.	488·2	487·0	..	..	..	..	..	..	..	..	..	..	..	148·6	..	..	..	..	..
		L.	485·9	484·2	..	419·8	410·0	394·3	397·4	..	..	..	..	..	..	153·6	..	..	..	..	..
844	♂	R.	479·0	475·8	..	..	..	..	..	..	..	..	..	287·0	279·7	146·6	..	..	..	..	..
		L.	..	..	..	..	..	..	..	329·0	327·6	255·4	242·0	..	..	..	..	..	..	..	..
854	♀	R.	..	..	..	..	..	..	..	315·4	313·2	260·0	247·8	..	..	150·0	117·6	119·0	..	..	..
		L.	..	..	..	..	..	..	..	304·1	303·0	..	..	..	..	149·5	..	..	..	..	..
862	♀	R.	421·0	418·0	..	..	..	323·0	333·0	295·7	293·0	..	208·0	238·4	235·3	..	..	..	..	..	..
		L.	..	..	..	347·0	337·5	323·0	333·0	286·4	284·0	216·2	204·2	235·2	231·2	133·2	..	..	..	..	..
863	♀	R.	..	..	..	353·0	345·0	332·0	335·0	..	..	234·6	224·0	..	•250·0	141·0	..	..	..	..	..
		L.	416·0	415·6	..	355·2	346·6	334·0	..	289·2	289·1	..	..	..	..	141·8	..	..	..	..	..
864	♂	R.	443·5	442·6	..	391·3	380·4	365·7	..	..	..	..	..	284·3	279·7	..	81·3	104·9	..	..	..
		L.	442 3	441·8	..	..	..	..	..	..	..	..	..	..	..	152·0	..	..	..	..	..
867	♀	R.	459·2	452·8	70·7	395·0	387·0	373·0	387·2	316·0	308·3	..	..	..	..	..	..	..	..	..	..
		L.	462·2	..	..	392·1	384·0	371·2	387·2	..	..	..	..	..	..	..	..	..	..	..	..
869	♀	R.	412·4	408·0	58·8	345·4	338·0	324·0	..	..	..	233·5	224·0	256·7	249·3	..	..	..	..	..	..
		L.	412·0	410·9	..	343·0	335·0	321·3	330·0	288·7	286·8	..	..	..	..	..	..	..	..	..	..
870	?	R.L.	..	..	..	..	..	l321·0	l332·8	l274·0	l272·3	r226·3	r215·0	l243·0	l239·0	..	..	..	..	..	..
871	♀	R.	434·8	432·7	65·5	380·0	371·0	356·0	..	304·4	297·6	..	..	271·0	266·0	..	..	..	..	..	..
		L.	433·0	431·0	66·8	379·2	371·4	356·8	..	..	..	245·2	231·6	..	..	..	..	..	..	..	..
873	♀	R.	..	..	..	..	..	331·2	344·0	..	..	228·6	217·3	..	..	..	99·3	108·3	..	..	..
		L.	411·5	..	..	355·0	346·2	333·0	..	..	..	..	..	..	..	..	..	..	..	..	..
874	♂	R.	?457·7	?456·1	..	387·0	377·0	360·5	..	..	..	253·0	239·2	?281·2	?274·7	158·0	..	..	..	..	..
		L.	446·2	445·2	..	..	..	..	..	321·0	..	250·5	237·2	..	..	..	..	..	..	..	..
875	♂	R.	..	..	..	403·7	396·0	379·3	..	357·0	352·2	..	..	..	..	..	..	..	..	..	..
875x	?	R.	..	..	..	..	..	..	..	335·9	334·5	..	..	..	..	..	..	..	..	..	..
876	?	R.	..	..	..	419·3	410·8	394·0	..	..	..	..	..	..	..	..	..	..	..	..	..
877	♂	R.	..	..	..	..	395·3	380·0	..	..	..	268·2	254·0	..	..	..	101·0	115·0	..	..	..
		L.	466·0	463·2	72·5	400·0	388·9	373·5	382·0	326·4	325·2	..	..	..	..	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
878	♀	R.	..	..	..	..	..	..	..	300·3	293·2	..	..	..	..	140·2	..	..	..	..	..
		L.	..	..	..	..	..	..	362·0	291·5	289·8	..	..	..	..	144·0	..	..	..	..	..
879	?	L.	..	..	..	..	..	..	..	311·8	..	..	..	..	..	..	..	..	..	..	..
880	♂	R.	..	..	..	..	..	349·3	363·3	326·2	322·7	248·4	233·2	267·6	263·6	..	..	..	..	..	..
		L.	433·0	428·2	..	..	..	..	364·0	..	..	249·2	233·6	270·3	263·7	149·5	..	..	..	..	..
881	♂	R.	..	..	..	385·8	375·3	360·9	374·3	..	..	..	..	..	270·4	..	..	..	..	..	..
		L.	456·0	..	..	379·0	370·3	357·0	..	314·5	..	255·8	242·0	275·2	270·3	..	..	..	..	98·3	126·7
882	♂	R.	..	..	..	..	..	..	..	..	..	261·0	247·0	..	..	149·1	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	255·0	241·2	275·5	270·0	..	..	..	..	..	..
883	♂	R.	..	..	..	..	..	..	..	317·0	314·8	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	336·6	..	322·0	..	..	232·5	265·0	261·7	..	..	..	..	..	..
884	♀	R.	..	..	..	..	..	..	381·4	..	..	252·8	241·0	..	..	..	106·0	126·6	..	..	..
		L.	..	..	..	396·8	387·0	374·3	..	..	..	..	..	275·6	269·6	156·0	..	..	..	..	..
1004	?	R.	..	..	..	338·0	329·0	315·3	..	..	..	..	..	..	..	..	..	..	..	..	..
1006	♂	R.	..	..	..	388·4	379·8	366·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	365·4	..	..	..	260·3	247·0	..	..	..	..	..	..	..	..
1007	?	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	148·0	..	..	..	..	..
1009	?	R.	..	..	..	..	..	..	..	..	..	265·8	251·5	..	..	..	..	..	..	..	..
1013	?	R.	..	..	..	..	..	..	333·0	..	..	..	..	..	..	..	..	..	..	..	..
1015	♀	R.	458·0	450·0	65·9	..	..	..	..	332·2	329·3	..	..	..	..	..	102·2	116·1	..	..	..
1017	?	R.	..	..	..	..	..	..	..	315·4	312·1	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	302·7	300·2	..	..	..	..	..	..	..	..	..	..
1022	?	R.	484·2	482·0	..	417·7	407·3	390·4	..	349·3	345·3	..	..	..	..	..	..	..	..	..	..
1025	?	R.	..	..	..	..	363·0	350·1	..	..	..	..	..	..	..	..	..	..	..	..	..
1026	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	120·0	..	..	..	..	..
1028	?	R.	435·8	427·0	63·6	376·0	365·5	353·0	365·2	..	..	..	..	..	..	..	..	..	..	..	..
		L.	441·4	433·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1031	♀	R.	..	..	..	349·5	341·2	328·5	..	284·4	282·1	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	349·0	342·0	329·4	..	..	..	..	..	..	238·0	..	..	..	..	..	..
1037	♀	R.	416·2	410·0	64·5	341·0	330·3	317·4	..	290·4	..	..	..	253·0	246·3	138·6	..	..	..	..	..
		L.	421·1	..	..	340·5	331·5	319·3	..	..	..	232·0	218·0	..	251·0	..	..	..	..	..	..
1040	♀	R.	441·0	438·0	64·7	..	..	..	..	307·2	304·5	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	304·3	301·8	..	..	..	..	..	..	..	..	..	..
1041	?	R.L.	r 450·0	r 443·0	..	l 381·2	l 371·3	l 357·2	l 369·0	..	..	..	..	..	..	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
1047	?	R.	..	..	..	..	..	..	359·8	..	..	..	..	..	..	..	..	..	..	..	..
1048	?	R.	..	..	..	347·2	338·0	325·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	422·0	417·3	71·1	348·3	339·2	326·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1100	?	R.L.	*l* 399·8	*l* 398·8	*l* 64·3	..	..	*l* 308·8	..	*l* 278·7	*l* 275·0	*l* 214·2	*l* 201·2	*r* 253·3	*r* 249·3	*r* 152·2	..	..	..	..	..
1101	♀	R.	..	..	..	390·0	380·2	366·6	..	..	..	..	..	..	..	128·0	..	..	..	..	..
		L.	..	..	..	390·4	380·9	368·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1102	♀	R.	442·0	436·2	72·7	372·7	363·0	345·5	..	321·0	319·2	250·3	235·6	271·2	265·0	136·8	..	..	149·8	96·0	113·2
		L.	447·2	443·3	..	376·5	366·8	350·3	..	315·1	314·0	..	..	..	..	136·8	..	..	..	97·0	111·0
1103	♀	R.	447·0	445·1	..	370·0	360·0	346·0	259·0	..	..	..	..	..	..	137·0	93·0	110·3	129·3	90·4	106·3
		L.	448·4	446·0	..	369·6	359·5	347·3	..	298·0	295·3	242·0	231·0	258·8	252·8	..	..	..	..	..	..
1104	♀	R.	399·0	393·9	63·1	328·0	320·3	307·0	326·3	..	..	220·4	207·0	..	..	..	..	..	..	..	..
		L.	..	..	..	330·2	323·0	310·2	..	277·1	273·6	..	..	..	..	..	..	..	..	..	..
1105	♀	R.	430·2	426·0	66·4	354·0	346·0	333·8	339·0	305·0	303·4	239·0	227·3	254·5	248·9	141·0	..	..	..	..	..
		L.	426·3	424·0	68·7	..	..	..	..	295·3	294·4	239·0	228·0	256·7	251·0	..	..	..	143·8	89·3	110·1
1106	♀	R.	421·0	416·0	65·1	353·0	343·6	331·4	346·0	298·3	296·8	..	..	259·2	253·1	132·3	..	..	..	..	..
		L.	422·3	418·3	62·6	356·3	346·4	333·5	344·2	290·3	287·3	236·1	224·5	..	..	..	..	..	..	..	..
1107	♀	L.	..	..	..	326·0	316·0	304·0	..	285·0	..	..	..	..	238·0	..	..	..	..	..	..
1109	♀	R.	..	..	..	347·0	337·0	324·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1180	?	R.	..	..	..	..	..	..	..	299·3	298·8	..	..	..	..	..	..	..	..	..	..
1212	♂	R.	..	..	..	..	..	356·0	..	..	..	235·2	223·8	..	..	152·0	78·0	110·9	..	..	..
		L.	..	..	..	..	..	..	..	..	..	..	..	..	..	151·6	..	..	..	..	..
1216	?	L.	..	..	..	352·0	344·6	332·3	..	..	..	..	..	..	..	..	..	..	..	..	..
1251	?	R.	..	..	..	358·0	348·3	335·0	343·5	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	358·8	350·5	337·0	348·0	..	..	..	..	..	..	..	..	..	..	..	..
127	?	L.	..	..	..	..	..	372·1	..	..	..	..	..	..	..	..	..	..	..	..	..
1300	♀	R.	..	..	..	331·4	326·4	312·0	..	..	..	219·5	208·0	243·0	236·3	..	..	..	..	..	..
		L.	392·0	390·3	..	331·8	326·8	312·8	310·2	..	..	..	..	..	..	142·1	..	..	..	..	..
1313	♀	R.	389·4	387·8	..	..	..	..	315·0	292·5	284·8	..	..	..	..	..	95·0	109·0	..	..	..
		L.	389·2	388·0	..	329·9	320·2	307·0	317·5	..	..	..	..	..	..	..	..	..	..	..	..
1330	♂	R.L.	..	..	..	..	..	..	*l* 382·8	*r* 328·2	*r* 325·8	..	..	..	..	..	..	..	..	..	..
1333	?	R.	..	..	..	353·9	344·3	330·5	..	..	..	..	..	..	..	..	..	..	..	..	..
1335	♀	R.	418·2	413·9	..	344·8	338·0	326·0	344·0	292·5	291·0	236·0	223·4	..	..	148·2	..	..	..	..	..
		L.	422·0	416·2	62·8	347·0	339·1	325·5	..	290·0	287 0	232·4	220·0	..	..	148·2	..	..	..	..	..
1344	♀	R.	..	..	..	..	..	..	321·0	..	..	234·0	223·0	..	..	119·7	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
1344	♀	L.	..	..	..	..	..	..	..	299·0	..	..	..	251·3	248·3	131·2	..	..	..	..	..
1349	♀	R.	414·0	412·0	..	..	..	..	..	307·2	306·3	..	..	..	..	..	89·8	105·8	..	..	..
		L.	410·3	408·9	..	..	..	..	324·0	..	..	..	..	..	..	..	..	..	..	..	..
1354	♂	R.	468·0	..	..	376·3	365·0	353·7	..	..	..	254·8	241·0	..	..	..	..	..	..	..	..
		L.	468·0	464·5	..	..	..	355·2	368·0	..	..	..	..	..	..	..	..	..	..	..	..
1362	?	L.	436·2	433·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1415	♂	R.	501·5	495·0	..	..	..	398·3	408·0	368·2	364·3	..	..	..	..	..	..	..	..	..	..
		L.	499 2	495·0	..	423·0	412·5	399·0	406·3	368·0	363·8	277·8	263·2	302·8	294·0	..	..	..	..	..	..
1415x	?	R.L.	*l* 448·0	*l* 444·5	..	*l* 373·0	*l* 364·2	*l* 349·5	..	*r* 331·2	*r* 329·2	*l* 255·4	*l* 242·0	..	..	..	..	..	..	..	..
1417	♂	R.	457·8	454·0	..	401·0	392·0	378·0	390·8	..	..	..	..	..	..	..	107·0	124·0	..	..	..
		L.	462·4	458·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1417*a*	♀	R.	..	..	..	323·0	313·8	301·8	315·0	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	324·0	314·7	303·0	316·2	..	..	..	..	233·2	228·0	..	..	..	..	..	..
1418	♂	R.	467·0	464·0	..	395·0	387·0	370·8	..	..	..	..	..	..	..	..	103·2	112·3	..	..	..
		L.	466·0	464·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1419	♀	R.	..	..	..	348·5	340·0	326·5	..	..	..	227·3	213·7	..	..	..	..	..	..	..	..
		L.	421·0	418·3	..	348·2	338·3	326·3	..	286·0	284·0	226·0	212·0	246·0	238·0	..	..	..	..	..	..
1430	♀	R.	406·0	400·8	..	342·3	329·5	317·0	337·5	..	..	..	..	..	..	..	..	..	..	..	..
		L.	401·4	398·5	..	..	..	..	336·3	..	..	..	..	..	..	..	..	..	..	..	..
1437	♂	R.L.	*r* 522·7	*r* 522·7	..	..	..	*r* 432·5	..	*l* 365·7	*l* 363·2	..	..	..	..	..	..	..	..	..	..
1443	♂	R.	471·4	470·0	..	391·5	382·4	366·8	..	330·0	327·6	..	..	277·3	273·0	..	..	..	..	..	..
		L.	468·4	467·8	..	395·8	385·3	370·0	..	328·2	323·2	..	..	..	..	..	..	..	..	..	..
1452	♂	R.L.	..	..	..	*l* 420·8	*l* 409·4	*l* 393·0	..	*r* 357·3	*r* 348·8	..	..	..	..	..	..	..	..	..	..
1456	♀	L.	417·3	414·3	..	..	..	..	..	298·0	294·0	..	..	..	..	..	..	..	..	..	..
1457	♀	R.	446·5	445·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1459	♀	L.	..	..	..	..	..	..	..	314·9	..	..	..	..	..	..	..	..	..	..	..
1460	?	R.	..	..	..	..	..	..	..	320·6	318·2	..	..	..	..	..	..	..	..	..	..
1462	?	L.	464·2	463·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1464*b*	?	L.	492·3	489·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1466	?	L.	448·0	446·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1468	♀	R.	433·0	430·2	..	364·0	353·3	339·3	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	435·2	431·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1469	?	R.	..	..	..	..	..	..	..	298·2	294·7	..	..	..	..	..	..	..	..	..	..
1475	?	R.L.	*r* 498·6	*r* 497·3	..	..	..	..	..	*l* 306·8	*l* 306·3	..	..	..	..	..	..	..	..	..	..

General Graves.—*Skeletons* (continued).

No.	Sex	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
1477	?	R.	446·2	438·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1491	?	R.	490·9	487·0	..	418·0	409·9	394·8	..	335·7	..	..	..	..	..	..	..	..	..	..	..
1503	♂	R.	455·7	454·0	..	388·0	378·8	361·2	369·5	..	..	..	..	..	..	..	101·1	108·9	..	..	..
		L.	457·7	457·3	..	391·6	381·2	362·8	373·0	..	..	..	..	..	..	..	..	..	..	..	..
1506	♂	R.	469·3	463·8	..	400·7	391·2	377·0	..	..	..	260·5	245·0	..	..	..	..	..	..	..	..
		L.	..	..	..	403·7	394·0	379·5	..	325·0	322·3	259·8	244·0	282·0	276·8	..	..	..	..	..	..
1545	♂	R.	536·5	531·8	..	437·9	428·6	412·2	..	..	..	286·2	273·0	..	..	..	..	..	..	..	..
		L.	530·2	528·2	..	442·0	429·7	413·0	..	378·5	376·7	..	..	..	..	170·6	..	..	..	..	..
1546	♂	R.	463·8	461·2	..	395·4	383·2	364·8	380·3	333·0	327·0	263·6	247·5	283·0	277·0	..	110·2	114·3	..	..	..
		L.	459·4	458·0	..	394·5	384·0	366·5	378·9	326·4	322·8	257·0	242·1	278·0	271·0	..	..	..	160·8	109·3	110·8
1552	?	L.	442·2	442·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1554	?	L.	..	..	..	397·0	387·2	373·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1557	?	R.	427·6	..	..	..	..	..	..	304·0	301·0	..	..	..	..	..	..	..	..	..	..
1586	♂	L.	466·5	465·0	..	..	..	..	..	322·0	315·0	..	..	..	..	..	..	..	..	..	..
1587	?	R.	490·4	486·4	..	..	..	..	..	344·2	343·8	..	..	..	..	..	..	..	..	..	..
		L.	489·8	488·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1587E	?	R.	..	..	..	..	..	..	..	334·5	334·0	..	..	..	..	..	..	..	..	..	..
1594	♀	R.	..	..	..	..	..	..	..	305·2	304·2	..	..	..	..	..	..	..	..	..	..
1603	?	L.	..	..	..	..	..	..	..	334·0	331·2	..	..	..	..	..	..	..	..	..	..
1604	♀	R.	..	..	..	..	..	..	..	282·4	281·0	..	..	..	..	..	..	..	..	..	..
1606E	?	R.	416·0	410·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1607	?	L.	..	..	..	..	..	..	..	296·1	295·8	..	..	..	..	..	..	..	..	..	..
1607W	?	R.	407·0	398·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1608	?	L.	..	..	..	..	..	..	..	290·3	285·0	..	..	..	..	..	..	..	..	..	..
1609	♂	R.	438·0	437·0	..	370·2	358·6	343·2	..	325·2	316·8	..	..	..	..	..	..	..	..	..	..
		L.	438·0	437·1	..	373·0	360·5	345·4	..	..	..	..	..	..	..	..	..	..	..	..	..
1610	?	R.	..	..	..	..	..	..	..	303·3	297·8	..	..	..	..	..	..	..	..	..	..
1611	?	R.	..	..	..	423·0	409·0	393·0	..	..	..	279·3	264·2	302·0	294·0	..	..	..	..	..	..
		L.	466·7	464·0	65·1	425·4	412·0	396·2	..	347·8	347·3	..	..	..	..	..	..	..	..	..	..
1612	?	R.	444·1	441·2	..	..	..	..	..	325·1	324·2	257·3	241·2	..	..	..	..	..	..	..	..
1613W	?	R.	..	..	..	366·0	358·0	345·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1614	?	R.L.	*r* 437·4	*r* 432·6	..	*l* 388·3	*l* 379·5	*l* 366·0	..	*r* 298·5	*r* 294·7	..	..	..	..	..	..	..	..	..	..
1619	?	R.	434·3	429·9	62·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1624	?	R.	413·0	407·1	69·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maxi-mum.	Ob-lique.	Neck.	Maxi-mum.	Ex-cluding spine.	Centre to centre.	Maxi-mum.	Maxi-mum.	Ob-lique.	Maxi-mum.	Centre to Centre.	Maxi-mum.	Ex-cluding styloid.	Maxi-mum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
1625	?	R.	411·6	405·5	59·6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1626	?	R.	459·7	453·0	73·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1628	?	R.	..	..	..	..	..	..	..	..	..	..	..	284·3	277·0	..	..	..	..	..	..
1631	?	R.L.	*r* 408·3	*r* 402·0	..	..	..	..	..	*l* 334·5	..	..	..	..	..	..	..	..	..	..	..
1632	?	R.	449·8	448·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1633	?	L.	412·7	408·6	60·9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1637	?	R.	421·7	420·1	64·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1639	?	L.	446·0	441·0	62·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1640	?	R.	473·2	467·3	72·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1641	♂	R.	460·7	454·3	70·0	..	..	354·3	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	379·5	369·0	354·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1643	♀	L.	464·2	462·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1644	♂	R.	..	..	..	405·3	396·3	380·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1651	♂	L.	452·2	451·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1653	?	R.L.	*r* 442·7	*r* 442·0	..	..	..	..	..	*l* 312·2	*l* 310·0	..	..	..	..	..	..	..	..	..	..
1661	?	R.L.	*r* 454·5	*r* 454·1	..	..	..	..	..	*l* 316·0	*l* 312·3	..	..	..	..	..	..	..	..	..	..
1666	♀	R.	447·7	442·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1667	♂	R.	459·8	459·0	..	..	..	..	..	330·3	327·3	..	..	..	..	..	..	..	..	..	..
1668	♂	R.	467·2	463·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	467·0	465·2	..	..	..	..	..	319·9	316·4	..	..	..	..	..	..	..	..	..	..
1669	?	R.	..	..	..	..	..	..	..	317·0	314·9	..	..	..	..	..	..	..	..	..	..
1670	♀	R.	437·7	433·2	..	382·8	374·7	362·7	..	300·3	297·7	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	293·0	292·2	..	..	..	..	..	..	..	..	..	..
1672	♀	R.	413·0	409·8	..	344·5	336·0	322·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1674	?	R.L.	*r* 431·8	*r* 431·2	..	*r* 364·0	*r* 353·0	*r* 339·8	..	*l* 298·0	*l* 296·5	..	..	..	..	..	..	..	..	..	..
1675	♀	R.L.	*r* 468·5	*r* 458·8	..	..	..	..	..	*l* 309·6	*l* 298·9	..	..	..	..	..	..	..	..	..	..
1676	?	R.	503·2	496·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1684	?	L.	449·3	447·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1685	♀	R.	444·3	440·0	..	..	..	..	..	310·3	307·5	..	..	..	..	..	..	..	..	..	..
1686	♀	R.	430·0	429·5	..	..	..	..	..	312·0	306·3	..	..	..	..	..	..	..	..	..	..
1687E	?	R.	..	..	..	369·8	362·2	350·6	..	..	..	..	..	..	..	..	..	..	..	..	..
1689	?	R.	..	..	..	..	..	..	..	319·5	313·8	..	..	..	..	..	..	..	..	..	..
1690	?	R.	528·9	519·0	..	..	..	..	..	371·5	361·8	..	..	..	..	..	..	..	..	..	..
1692	♂	R.	427·3	424·8	..	..	..	..	..	313·3	312·0	..	..	..	..	..	..	..	..	..	..

General Graves.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maxi-mum.	Ob-lique.	Neck.	Maxi-mum.	Ex-cluding spine.	Centre to centre.	Maxi-mum.	Maxi-mum.	Ob-lique.	Maxi-mum.	Centre to centre.	Maxi-mum.	Ex-cluding styloid.	Maxi-mum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
1692	♂	L.	..	..	..	..	..	..	..	310·4	309·0	..	..	..	..	..	..	..	..	..	..
1718	?	R.	437·2	434·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1720	?	L.	423·3	418·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1729	♂	R.	487·4	484·2	..	422·0	411·2	394·9	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	486·4	485·0	..	423·4	414·8	399·3	..	334·0	331·0	..	..	..	..	..	..	..	..	..	..
1733	♂	R.L.	r451·0	r449·7	..	r381·0	r373·8	r359·4	..	l314·0	l310·0	..	..	..	l269·9	..	..	..	..	..	..
1735	?	R.	451·8	447·0	..	377·3	369·3	357·0	..	..	..	..	..	269·0	263·8	..	..	..	..	..	..
		L.	455 7	453·3	..	372·0	362·2	351·0	..	..	..	244·2	234·0	..	..	..	..	..	..	..	..
1737	?	L.	..	..	..	..	..	..	..	333·0	328·0	..	..	..	..	..	..	..	..	..	..
1738	?	R.L.	..	..	..	r372·5	r363·8	r348·0	..	l294·2	l293·5	..	..	..	..	..	..	..	..	..	..
1739	♀	R.	448·0	436·0	..	380·2	369·0	352·5	..	..	..	..	..	280·0	277·2	..	..	..	..	..	..
		L.	447·9	437·2	..	..	..	..	..	321·0	315·8	254·7	242·6	..	..	..	..	..	..	..	..
1739x	♀	R.	407·0	396 5	..	340·0	329·0	314·5	..	295·3	289·4	227·3	214·6	247·2	242·2	..	..	..	..	..	..
		L.	408·0	..	..	339·0	329·0	313·5	..	289·3	284·0	..	..	242·2	237·3	..	..	..	..	..	..
1743	♀	L.	425·2	420·0	..	368·3	359·3	345·3	..	..	..	..	..	..	..	..	..	..	..	..	..
1745	♀	R.	430·0	427·6	..	..	..	..	..	297·4	294·2	..	..	..	..	..	..	..	..	..	..
1746	?	L.	..	..	..	..	..	..	..	293·9	292·0	..	..	..	..	..	..	..	..	..	..
1747	?	R.	..	..	..	..	..	..	..	329·3	328·0	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	315·5	314·0	..	..	..	..	..	..	..	..	..	..
1748	?	R.	457·0	453·0	..	..	..	..	..	330·9	329·2	..	..	..	..	..	..	..	..	..	..
1751w	♀	R.	410·8	408·2	..	341·8	334·0	321·3	..	288 2	285·2	..	..	..	..	..	..	..	..	..	..
		L.	409·8	408·0	..	343·5	334·7	322·8	..	282·0	280·0	231·3	219·5	253·0	248·8	..	..	..	..	..	..
1751E	♀	R.	402·0	398·9	..	349·3	340·4	325·7	..	289·3	288·0	231·3	218·2	253·1	250·4	..	..	..	..	..	..
		L.	404·0	401·3	..	352·0	341·0	329·0	..	282·0	278·3	227·0	214·0	250·5	247·0	..	..	..	..	..	..
1754	♀	R.	410·2	407·0	..	..	..	..	..	286·3	284·7	..	..	..	..	..	..	..	..	..	..
1755	?	R.	476·2	471·0	..	..	..	..	..	334·0	329·8	..	..	..	..	..	..	..	..	..	..
1758	♀	R	437 3	435·0	..	366·3	357·8	344·0	..	303·0	302·8	..	..	..	..	..	..	..	..	..	..
		L	..	..	..	362·5	353·6	340·8	..	299·8	296·0	..	..	..	..	..	..	..	..	..	..
1774	♀	R.	442·3	435·5	..	373·3	365·3	352·3	..	300·2	296·0	..	..	253·0	248·0	..	..	..	..	..	..
		L.	437·8	433·9	..	376 3	367·3	354·4	..	293·9	290·2	..	..	245·0	239·8	..	..	..	..	..	..
1775	♂	R.	416·8	414·0	..	373·3	363·4	348·0	362·0	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	366·3	356·0	341·8	..	310·0	309·8	..	..	..	..	..	..	..	..	..	..
1781	?	R.	..	..	..	..	..	..	..	301·0	299·3	..	..	..	..	..	..	..	..	..	..
1786	?	R.	435·0	432·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

GENERAL GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
1787	?	R.	453·0	448·3	..	375·0	363·3	349·9	..	319·6	313·8	247·4	234·5	266·0	261·6	..	..	..	..	..	..
		L.	451·5	449·0	..	379·5	368·0	355·0	..	319·0	312·6	..	..	265·4	264·0	..	..	..	..	..	..
1789	?	R.L.	*r*488·5	*r*483·2	..	..	..	..	..	*l*320·0	*l*318·0	..	..	..	..	..	..	..	..	..	..
1795	♂	R.	464·2	462·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1796	?	R.	455·0	451·1	..	385·0	377·4	362·0	..	..	..	257·5	243·3	277·0	270·3	..	..	..	..	..	..
		L.	453·4	451·3	..	386·8	377·3	363·5	..	..	..	..	..	275·6	269·5	..	..	..	..	..	..
1798	♀	R.L.	*l*398·9	*l*394·0	..	..	..	..	..	*r*277·0	*r*275·7	*r*216·5	*r*205·0	*r*240·8	*r*236·5	..	..	..	..	..	..
1803	♂	R.L.	*l*479·4	*l*475·8	..	*r*414·0	*r*403·3	*r*386·2	..	?*l*291·0	?*l*289·0	..	..	..	..	..	..	..	..	..	..
1814	♀	R.	..	..	..	366·3	358·0	344·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	425·3	422·0	..	364·3	356·0	343·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1817	♀	R.	..	..	..	..	..	..	..	303·0	299·8	..	..	265·3	260·8	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	301·2	298·8	240·8	228·0	..	..	..	..	..	..	..	..
1820E	?	R.	..	..	..	404·0	395·3	378·3	..	..	..	..	..	..	..	155·1	..	..	..	..	..
		L.	462·3	459·0	..	..	..	..	..	..	..	..	..	..	..	155·2	..	..	..	..	..
1820R	?	R.L.	..	..	..	..	..	*r*398·5	..	*l*305·0	*l*304·3	..	..	..	..	..	..	..	..	..	..
1820W	?	R.	454·0	447·0	66·7	389·0	377·4	365·4	..	313·1	312·9	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	394·0	381·3	367·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1839	♂	L.	499·2	498·3	..	419·0	407·8	393·0	..	350·4	344·5	..	..	..	..	..	..	..	..	..	..
1849	?	R.L.	*r*436·5	*r*431·1	..	..	..	..	..	*l*321·0	*l*317·6	..	..	..	..	..	..	..	..	..	..
1856W	♂	R.	485·0	482·0	..	414·0	404·0	388·3	..	..	..	..	..	..	..	..	..	..	..	..	..
1856E	?	L.	478·2	470·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1860	♀	R.L.	..	..	..	*r*367·5	*r*359·8	*r*346·3	..	..	..	..	..	*l*251·4	*l*246·8	..	..	..	..	..	..
1863	♀	R.	..	..	..	..	..	..	..	..	..	238·2	227·2	..	..	..	..	..	..	..	..
1865	?	R.	433·2	422·6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1866	♂	R.L.	*r*488·0	*r*485·3	..	..	..	..	..	*l*332·0	*l*326·5	..	..	..	..	..	..	..	..	..	..
1869	?	R.	446·5	443·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1874	?	R.	418·0	411·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1875	♂	R.	442·0	441·0	..	376·5	369·0	354·5	..	318·0	317·1	..	..	272·0	267·8	..	..	..	..	..	..
		L.	450·0	449·4	..	381·0	372·0	357·5	..	..	..	..	..	..	..	..	..	..	..	..	..
1878	♂	R.	494·3	486·4	..	423·8	410·2	396·2	..	..	..	..	..	305·0	298·0	..	..	..	..	..	..
		L.	495·0	489·0	..	..	..	..	..	347·7	344·0	..	..	..	..	..	..	..	..	..	..
1879	?	R.	..	..	..	413·5	405·0	388·4	..	346·3	342·2	270·0	255·6	..	..	..	..	..	..	..	..
		L.	475·3	473·2	..	415·2	406·2	390·4	..	343·8	339·5	269·0	254·6	..	..	..	..	..	..	..	..
1885	?	R.L.	..	..	..	*r*361·3	*r*354·2	*r*342·0	..	*l*317·0	*l*307·2	..	..	..	..	..	..	..	..	..	..

General Graves.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maxi-mum.	Ob-lique.	Neck.	Maxi-mum.	Ex-cluding spine.	Centre to centre.	Maxi-mum.	Maxi-mum.	Ob-lique.	Maxi-mum.	Centre to centre	Maxi-mum.	Ex-cluding styloid.	Maxi-mum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
1888	?	L.	..	..	..	366·8	358·0	338·8	..	..	..	..	..	..	..	..	..	..	..	..	..
1890	♂	R.L.	*l* 462·0	*l* 460·3	*l* 74·0	..	..	..	..	*r* 321·5	*r* 316·0	..	..	..	..	..	..	..	..	..	..
1896	?	R.	..	..	..	403·0	395·0	381·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1898	?	R.	460·7	458·8	79·5	396·0	386·2	368·3	..	335·5	332·1	..	..	..	..	..	..	..	..	..	..
1899	♂	R.L.	*r* 481·5	*r* 479·8	*r* 84·0	*l* 406·5	*l* 395·3	*l* 379·5	..	*r* 326·8	*r* 325 8	..	..	*r* 300·2	*r* 295·5	..	..	..	..	..	..
1901	?	L.	..	..	..	..	..	347·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1902	♀	R.	..	..	..	..	..	..	..	328 4	324·2	..	..	..	..	..	..	..	..	..	..
1905	?	R.	..	..	..	..	..	..	..	294·2	292·3	..	..	..	..		..	..	..	..	..
1909	?	R.	..	..	..	348·5	340·2	326·0	..	..	..	..	..	..	..	..	..	..	..	..	..
1914	♀	R.	426·0	421·0	..	358·2	350·0	337·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	422·2	421·0	..	..	..	..	..	290·0	288·0	..	..	..	..	..	..	..	..	..	..

General Graves.—*Non-skeletons.*

No Number.	F.l. 476·0, 473·0; 463·8, ——; T.r. 396·3, 386·0, 372·0; 352·8, 344·2, 331·3; U.r. 266·0, 258·4.
30.	H.l. 297·0, 296·3.
643.	R.r. 228·4, 215·0.
733.	Cl.r. 126·7.
880.	H.l. 307·0, ——.
1670.	H.l. 289·2, 288·2.
1739.	U.r. 286·2, 281·8.
1856w.	F.r. 484·8, 481·6.

Q GRAVES.—*Skeletons.*

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
9 inside	?	L.	420·3	418·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
18	?	R.	..	..	..	398·0	390·5	375·7	..	..	..	..	..	..	..	..	..	..	..	..	..
26	?	R.	..	..	..	422·6	412·3	398·9	..	..	..	..	..	..	..	..	..	..	..	..	..
37	♂	R.	493·3	491·2	79·2	..	..	..	..	367·8	359·5	..	..	299·8	292·3	..	..	..	..	..	..
		L.	499·0	496·9	..	437·3	423·7	407·0	..	..	..	..	..	299·7	291·9	..	..	..	..	..	..
43	♂	R.	..	..	..	..	..	..	..	323·0	319·0	..	..	285·5	280·0	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	317·9	317·0	266·7	253·2	..	..	..	..	..	..	..	..
45	?	L.	348·0	344·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
47	?	R.	..	..	..	362·0	351·3	339·2	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	362 2	351·5	340·4	..	..	..	..	..	..	..	..	..	..	..	..	..
50	♀	R.	..	..	..	..	..	324·8	..	304·0	303·8	..	..	..	..	144·1	..	..	..	..	..
		L.	..	..	..	350·3	341·0	326·5	..	294·4	293·9	..	..	..	..	142·0	..	..	..	..	..
54	♂	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	98·9	124·3
		L.	..	..	..	..	..	..	..	..	..	..	..	..	..	151·0	108·5	104·3	..	98·5	121·4
59	♂	R.	475·0	472·0	..	..	..	..	..	328·0	322·2	..	..	288·0	281·0	..	99·5	111·2	..	..	..
		L.	472·0	470·0	..	416·5	407·0	394·3	..	326·0	320·3	264·8	253·0	283·5	275·8	..	..	..	..	..	..
59BB	?	L.	..	..	..	400·0	391·1	378·0	..	..	..	..	..	..	..	..	..	..	..	..	..
67	♂	R.	..	..	..	..	..	352·3	..	305·5	302·3	253·8	239·5	278·4	271·5	151·0	..	..	..	..	..
		L.	..	..	..	..	..	350·6	366·3	304·6	301·5	252·2	238·2	273·2	265·3	..	..	..	..	..	..
70	?	R.	..	..	..	351·4	344·2	329·3	342·3	..	..	..	..	..	..	..	..	..	..	..	..
73	?	R.L.	r452·4	r451·3	..	l393·5	l382·6	l369·0	..	..	..	..	..	..	..	..	..	..	..	..	..
74	?	R.L.	..	..	..	..	..	..	r369·5	..	..	..	..	l268·8	l261·3	..	..	..	..	..	..
77E	?	R.	..	..	..	..	..	..	..	313·0	309·9	278·6	265·0	..	..	..	..	..	..	..	..
		L.	460·0	454·0	..	..	..	..	..	305·5	304·0	..	..	295·0	290·8	..	..	..	..	..	..
77W	?	R.L.	..	..	..	l380·8	l370·3	l359·0	..	..	..	r240·9	r230·0	..	..	..	..	..	..	..	..
79	?	R.	..	..	..	..	..	..	..	..	..	223·0	210·3	..	..	..	..	..	..	..	..
81	?	R.	..	..	..	..	..	..	..	..	..	266·2	251·8	..	..	..	..	..	..	..	..
82	♂	R.L.	..	..	..	..	..	..	..	..	..	..	..	..	r260·2	l146·3	88·1	97·2	..	..	..
83	♂	R.	..	..	..	366·5	356·4	344·0	..	305·2	305·0	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	366·0	356·2	344·2	..	..	..	..	..	..	..	..	..	..	..	..	..
85	?	L.	..	..	..	..	..	..	..	..	..	..	..	..	..	154·3	..	..	..	..	..
87	?	R.	..	..	..	..	..	..	375·3	..	..	..	..	..	..	..	..	..	..	..	..
92½	♀	R.L.	..	..	..	l365·2	l357·0	l341·3	..	..	..	..	..	..	..	r129·8	..	..	..	..	..

Q GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
101	?	R.	..	..	..	..	..	..	..	..	..	259·2	246·5	..	..	..	..	..	..	..	..
102	?	R.L.	..	..	..	r322·3	r314·0	r300·0	..	l 270·0	..	..	..	..	..	..	..	..	..	..	..
103½	♀	R.	404·3	403·3	..	338·0	329·4	317·2	..	288·0	286·3	..	..	..	..	132·3	..	..	..	..	..
		L.	..	..	..	335·0	326·5	315·0	..	281·2	279·0	..	..	..	..	130·3	..	..	..	..	..
105	?	R.	419·6	417·0	..	353·2	340·8	326·5	..	306·0	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	351·0	339·0	324·5	..	..	..	..	..	..	..	..	..	..	..	..	..
105N	?	R.	..	..	..	368·0	358·3	344·0	..	..	..	..	..	..	..	..	..	..	..	..	..
108	?	L.	..	..	..	..	..	..	..	293·0	290·7	..	..	..	..	..	..	..	..	..	..
109	♀	R.	439·0	436·0	..	368·3	357·2	342·5	..	..	..	..	..	..	..	144·0	..	..	..	..	..
		L.	?433·2	?430·4	..	372·8	362·2	346·8	..	..	..	..	..	..	..	..	..	..	..	..	..
118	♂	R.	497·0	490·5	..	414·0	403·3	390·5	..	..	..	276·3	263·0	298·5	290·6	173·5	..	..	..	..	..
		L.	491·3	487·5	..	409·0	400·0	385·5	..	..	..	277·0	262·2	297·6	291·6	171·1	..	..	..	..	..
138	♂	R.	437·5	434·6	..	374·0	364·5	352·3	..	..	..	..	..	..	..	144·6	..	..	..	..	..
		L.	433·7	432·0	..	372·2	362·3	349·2	..	309·0	308·5	..	..	..	..	..	..	..	..	..	..
148	?	R.	..	..	..	..	..	..	..	..	..	..	..	278·0	274·3	..	..	..	..	..	..
158	?	R.	..	..	..	..	..	338·5	..	..	..	..	..	..	..	..	..	..	..	..	..
160	?	R.	..	..	..	..	..	..	..	329·0	326·0	..	..	..	..	160·8	..	..	..	..	..
161	?	L.	365·0	363·6	..	378·3	369·3	357·0	..	..	..	..	..	..	..	..	..	..	..	..	..
171	♂	R.	..	..	..	398·0	388·3	373·0	..	..	..	264·2	251·0	282·0	277·0	..	..	..	..	..	..
		L.	459·0	458·0	81·0	398·2	389·0	372·3	..	315·0	313·0	259·4	246·0	..	..	..	..	..	..	..	..
172	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	122·4	..	..	..	..	..
174	?	R.L.	..	..	..	..	..	..	..	l 331·3	l 330·0	r257·0	r244·0	..	..	..	..	..	..	..	..
176	?	R.L.	r462·9	r459·8	..	r388·3	r378·2	r363·8	..	..	..	..	..	l 288·6	l 282·0	..	..	..	..	..	..
176*a*	?	L.	..	..	..	..	..	..	..	297·0	297·0	..	..	..	..	..	..	..	..	..	..
176B	♂	R.	434·5	432·3	..	363·2	354·5	342·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	440·3	437·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
177	?	R.	..	..	..	..	..	..	..	307·0	303·0	242·4	229·3	..	..	..	..	..	..	..	..
		L.	432·0	427·2	..	..	..	..	..	302·7	298·8	..	..	..	..	..	..	..	..	..	..
178	♀	R.	437·0	434·8	..	..	..	..	..	309·5	304·7	..	..	..	..	..	105·6	120·5	..	..	..
		L.	..	..	..	..	..	..	..	304·5	299·8	..	..	262·3	257·0	..	..	..	..	..	..
186	?	R.	?427·3	?425·3	?70·5	356·3	349·0	337·0	..	307·3	302·0	..	..	..	..	..	..	..	..	..	..
		L.	?440·7	?436·7	..	..	..	338·0	..	..	..	..	..	..	..	..	..	..	..	..	..
191	?	R.	..	..	..	379·2	370·5	358·0	..	319·0	317·0	236·0	223·2	257·0	254·0	..	104·0	118·4	..	..	..
		L.	..	..	..	..	..	..	..	313·0	312·0	236·4	224·1	..	..	..	..	..	..	..	..

Q Graves.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
201	♂	R.L.	..	..	..	..	..	..	..	*l* 320·3	..	*r* 260·2	*r* 246·0	..	*l* 270·2	..	..	..	..	..	..
202	♂	R.L.	*l* 408·0	*l* 406·2	..	*r* 332·0	*r* 322·0	*r* 311·2	..	*l* 275·0	*l* 273·0	..	..	..	..	..	..	..	..	..	..
203	♂	R.	462·4	459·8	..	..	..	..	..	328·1	323·0	..	..	..	..	..	..	..	..	..	..
208–1	?	R.	470·5	469·4	..	384·3	373·2	357·7	..	336·0	324·0	262·0	249·5	282·9	280·2	..	..	..	..	..	..
		L.	466·5	464·9	..	383·0	370·9	355·0	..	333·0	325·0	258·5	246·0	278·8	277·3	..	..	..	..	..	..
208–3	♂	R.	..	..	..	..	..	..	..	336·5	..	..	..	..	..	..	..	..	..	..	..
212	?	R.L.	..	..	..	*l* 357·2	*l* 347·2	*l* 336·0	..	*l* 326·0	*l* 324·5	*r* 226·8	*r* 215·0	*l* 248·3	*l* 241·3	..	93·4	117·8	..	..	..
212–1	?	R.	361·5	355·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	358·5	356·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
212–2	♀	R.	..	..	..	..	..	..	..	252·3	251·2	..	..	..	..	..	..	..	..	..	..
		L.	.	..	..	..	..	..	..	247·6	245·8	..	..	..	..	..	..	..	..	..	..
215	♂	R.L.	*l* 492·0	*l* 488·0	..	..	..	..	..	*r* 347·0	*r* 342·3	*r* 277·7	*r* 263·4	..	..	..	..	..	..	..	..
216	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	281·5	..	..	..	..	..	..
217	♀	R.L.	..	..	..	..	..	..	..	*r* 286·0	*r* 286·0	..	..	*l* 244·8	*l* 239·0	..	..	..	..	..	..
222	?	L.	..	..	..	..	..	..	..	..	..	..	235·0	..	..	..	..	..	..	..	..
226	♂	R.	..	..	..	..	..	..	..	340·3	339·0	..	..	..	..	..	..	..	..	..	..
		L.	462·5	461·0	..	..	..	..	..	329·0	325·0	..		..	..	..	..	..	..	..	..
229	♂	R.	..	..	..	389·5	378·8	365·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	476·0	471·3	..	395·0	..	..	..	316·6	310·0	..	..	..	..	..	..	..	..	..	..
237	♂	R.	481 2	476·0	..	..	..	..	..	328·0	322·3	..	..	..	..	..	..	..	..	..	..
		L.	475·0	469·8	..	394·6	384·5	372·0	..	331·6	325·1	..	..	..	..	..	..	..	..	..	..
241	♂	R.L.	..	..	..	..	..	*r* 369·2	..	..	..	..	..	..	*l* 276·4	..	..	..	..	..	..
252	♀	R.	..	..	..	370·4	362·8	348·3	..	303·5	298·7	229·5	215·8	..	..	136·1	..	..	..	..	..
		L.	431·2	428·0	..	368·8	361·1	347·3	..	298·3	294·0	..	..	253·0	246·3	..	..	..	..	..	..
254	♀	L.	433·8	427·0	63·7	..	..	..	.	..	..	..	..	..	..	..	..	..	..	..	..
265	♀	R.	424·0	423·0	70·3	357·0	349·0	333·0	340·3	306·5	300·0	235·2	223·4	254·8	254·0	..	..	..	..	..	..
		L.	433·8	430·5	..	358·8	350·0	335·0	343·2	.	..	232·2	218·8	250·4	246·0	135·3	..	..	140·2	91·8	99·7
274	?	R.	..	..	..	385·4	375·8	364·0	..	..	..	251·0	239·3	272·0	267·3	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	309·0	306·0	246·0	234·0	..	..	..	..	..	..	..	..
276	♀	R.	..	..	..	..	..	..	..	285·2	282·1	215·0	203·4	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	303·5	..	282·0	280·1	208·2	198·2	..	..	..	..	..	..	..	..
278	?	R.	387·8	385·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
288	♀	R.	..	..	..	373·0	364·3	350·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	437·0	434·8	..	372·8	363·5	349·2	..	..	..	..	..	..	..	..	..	..	..	..	..

Q GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length	Breadth	Length.	Breadth	Infra-spinous length.
297	?	R.	424·2	417·3	..	363·0	353·0	337·2	354·6	302·2	298·0	238·9	227·0	260·0	257·0	..	..	..	..	..	..
		L.	..	..	..	363·0	352·3	338·0	..	293·2	292·0	..	..	262·5	256·8	..	..	..	..	..	..
299	♀	R.	..	..	..	339·7	331·0	318·2	..	..	..	224·5	213·6	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	274·3	271·2	219·3	208·0	237·0	232·0	..	..	..	..	..	..
303	?	R.	426·3	422·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
305	♀	R.	..	..	..	347·0	337·4	325·3	..	289·2	288·9	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	348·0	337·0	324·8	..	287·7	285·8	236·0	222·0	..	..	138·0	..	..	..	..	..
311	?	R.	..	..	..	..	..	..	..	311·3	309·0	243·2	231·0	..	..	137·3	..	..	..	..	..
		L.	..	..	..	384·0	375·0	361·1	..	307·1	302·0	242·8	231·0	..	..	..	..	..	..	..	..
313	?	L.	..	..	..	..	..	..	..	323·2	321·4	..	..	..	..	..	..	..	..	..	..
320	♀	R.	409·6	408·0	64·7	336·2	328·1	313·3	..	287·0	284·0	..	..	..	..	..	..	..	..	..	..
		L.	413·2	411·2	..	..	..	..	..	..	..	230·0	220·0	252·0	249·0	..	..	..	..	..	..
322	♂	R.	..	..	..	378·2	371·5	355·0	..	311·2	307·0	..	..	..	..	..	..	..	..	..	..
		L.	448·0	441·2	72·1	376·0	368·3	353·0	..	307·0	301·2	239·8	225·6	..	..	..	..	..	..	..	..
323	♂	R.	431·0	428·0	..	..	..	..	..	..	..	243·8	231·0	..	..	..	..	..	..	..	..
		L.	430·3	428·0	..	363·3	354·0	339·0	..	..	..	..	..	260·0	255·0	..	..	..	..	..	..
324	♂	R.	..	..	..	..	..	385·0	..	342·8	338·1	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	334·3	331·2	..	..	..	..	157·2	..	..	..	..	..
325	♂	R.	430·4	429·8	68·4	..	..	..	..	..	..	241·7	227·1	..	..	147·3	98·0	107·3	..	..	..
		L.	437·5	436·2	67·7	358·0	348·3	335·3	..	307·8	305·0	..	..	..	..	..	..	..	..	..	..
326	♀	R.L.	*r* 426·2	*r* 425·8	*r* 63·6	*r* 368·0	*r* 357·2	*r* 343·0	..	*l* 297·5	*l* 291·2	..	..	*l* 249·6	*l* 246·0	..	..	..	..	..	..
333	?	R.	..	..	..	393·5	382·0	367·0	..	..	..	..	..	..	..	..	..	..	..	..	..
334	?	L.	503·0	501·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
336	?	L.	434·3	433·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
342	♀	R.	396·0	390·0	63·1	317·2	307·0	292·1	309·0	..	..	..	..	235·5	228·5	..	81·8	100·8	..	..	..
		L.	400·7	394·0	62·4	350·3	340·8	328·0	311·3	268·0	268·0	..	..	..	..	..	..	..	..	..	..
344	♀	R.	442·0	435·3	..	348·3	339·0	326·0	337·0	311·0	306·0	233·0	222·0	255·0	249·0	..	..	..	..	..	..
		L.	439·0	435·2	..	..	..	..	..	304·0	298·3	229·0	218·0	..	..	..	..	..	..	..	..
347	♀	R.	..	..	..	..	..	329·5	..	301·1	299·0	216·0	204·5	..	251·0	127·0	..	..	..	..	..
		L.	410·2	407·0	66·1	..	..	..	..	293·4	291·0	..	..	?239·1	?234·5	..	..	..	..	..	..
353N	?	R.	451·8	450·0	77·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	454·8	451·8	76·5	389·0	380·0	362·2	..	..	..	..	..	..	..	..	..	..	..	..	..
353S	?	R.	..	..	..	..	..	..	..	288·0	287·8	..	..	..	..	..	..	..	..	..	..
356	?	R.	..	..	..	..	..	..	..	..	..	253·0	241·5	..	..	..	..	..	..	..	..

Q GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maxi-mum.	Ob-lique.	Neck.	Maxi-mum.	Ex-cluding spine.	Centre to centre.	Maxi-mum.	Maxi-mum.	Ob-lique.	Maxi-mum.	Centre to centre.	Maxi-mum.	Ex-cluding styloid.	Maxi-mum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
359–3	♂	R.	448·4	443·0	66·1	..	..	..	..	318·2	317·7	253·2	241·3	..	..	152·0	82·8	108·3	..	..	..
		L.	452·2	446·5	60·3	..	..	..	..	316·0	315·0	..	..	270·2	261·0	..	..	..	..	..	..
363	♂	R.	..	..	..	..	..	..	..	311·2	..	..	..	268·0	261·1	..	..	..	..	..	..
		L.	441·4	438·2	..	368·0	359·5	344·5	..	308·0	..	..	..	..	..	..	..	..	..	..	..
376	♀	R.L.	..	..	..	..	..	*l* 318·0	..	..	..	*r* 224·0	*r* 213·2	..	..	..	..	..	..	..	..
377	♀	R.	444·0	442·5	..	..	..	..	369·5	..	..	..	..	278·0	273·0	136·2	..	..	..	..	..
		L.	444·5	443·2	..	361·3	351·0	339·3	..	318·7	318·0	257·0	245·2	278·5	275·2	..	98·0	112·6	..	..	..
379	?	R.L.	*l* 412·4	*l* 409·0	*l* 68·3	*r* 333·2	*r* 324·3	*r* 312·1	..	..	..	..	..	..	..	..	..	..	..	..	..
383	♂	R.	..	..	..	..	..	358·0	..	..	..	..	..	..	..	..	..	..	..	..	..
384	♀	R.	378·3	376·2	58·9	..	..	..	..	279·8	278·3	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	274·0	272·2	..	..	211·0	199·0	..	..	..	..	..	..
396	?	L.	..	..	..	..	..	..	..	322·2	322·0	..	..	..	..	..	..	..	..	..	..
400	♂	R.	..	..	..	..	..	..	..	..	..	..	..	273·0	270·0	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	..	..	..	267·0	..	..	..	..	..	..
401	♂	L.	488·4	488·0	..	..	..	..	..	324·3	320·7	..	..	..	..	..	..	..	..	..	..
411	♀	R.L.	..	..	..	..	..	..	..	..	..	..	*r* 221·2	*r* 256·8	*r* 253·4	*l* 150·2	..	..	..	..	..
412	♂	R.	..	..	..	398·3	389·8	374·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	375·1	..	338·0	337·0	..	..	286·3	277·3	..	..	..	..	..	..
414	?	R.	..	..	..	..	..	..	..	280·2	279·5	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	278·0	277·2	220·0	207·0	238·5	233·8	..	..	..	..	..	..
415	?	R.L.	*l* 448·2	*l* 447·4	*l* 74·5	*r* 396·5	*r* 387·2	*r* 372·3	..	?*l* 272·0	?*l* 270·3	..	..	..	..	..	91·3	103·8	..	..	..
417	?	R.	..	..	..	359·3	349·4	335·3	..	289·0	286·0	..	..	..	..	..	..	..	..	..	..
		L.	414·7	412·8	66·6	363·0	354·0	341·2	..	286·7	284·8	..	..	..	..	..	..	..	..	..	..
430A	?	L.	..	..	..	..	..	..	..	..	..	..	..	246·0	241·0	..	..	..	..	..	..
431B	♀	R.	446·0	440·8	72·7	380·5	369·8	356·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	447·3	443·5	75·1	381·5	371·1	357·0	..	..	..	..	..	..	..	..	..	..	..	..	..
435	?	L.	422·3	420·6	70·4	..	..	..	..	284·0	277·2	..	..	..	..	..	..	..	..	..	..
436	♀	R.	434·0	432·0	..	376·3	367·0	352·0	..	314·3	309·9	..	..	..	..	..	..	..	..	..	..
		L.	449·3	446·4	67·4	..	..	..	..	309·8	305·4	..	..	261·2	257·5	..	..	..	..	..	..
437	?	R.	435·3	..	..	370·0	..	..	..	313·0	311·2	248·9	234·5	..	..	..	..	..	..	..	..
		L.	..	..	..	365·5	354·3	339·5	..	308·3	306·7	246·0	232·0	..	..	..	..	..	..	..	..
438	♂	R.L	*l* 428·0	*l* 428·5	..	*r* 377·5	*r* 368·4	*r* 353·0	..	*l* 312·1	*l* 307·0	..	..	..	..	..	..	..	..	..	..
439	♂	R.	..	..	..	..	..	..	..	304·3	300·3	246·2	233·0	265·4	264·7	140·0	..	..	..	..	..

Q Graves.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
439	♂	L.	431·8	..	..	..	..	..	..	299·0	294·3	..	..	..	..	..	..	..	..	..	..
445	?	R.	..	..	..	372·5	366·5	353·6	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	434·0	428·3	..	371·0	361·0	348·0	..	..	..	..	..	..	..	..	..	..	..	..	..
466(4)	♂	R.	411·8	..	..	..	..	..	..	287·0	283·5	221·2	209·8	..	..	..	..	..	..	..	..
		L.	411·2	407·0	..	343·3	334·0	320·0	..	280·0	276·0	..	..	242·8	236·6	..	..	..	..	..	..
472	?	R.L.	*l* 412·0	*l* 407·7	*l* 58·6	*l* 347·5	*l* 338·4	*l* 326·0	..	..	..	..	..	..	..	*r* 123·5	..	..	..	..	..
480	?	R.	..	..	..	..	..	..	..	..	..	227·0	214·3	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	224·0	211·8	..	..	..	..	..	..	..	..
481	?	R.	..	..	..	..	..	..	..	..	..	..	..	271·0	265·2	..	..	..	..	..	..
482	♀	R.	..	..	..	..	..	297·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	449·0	445·2	74·5	372·0	361·3	348·0	..	..	..	..	..	..	..	..	..	..	..	..	..
483	?	L.	..	..	..	384·0	373·4	358·2	..	..	..	..	..	..	..	..	..	..	..	..	..
487	♀	L.	..	..	..	..	..	..	..	298·3	292·3	..	..	..	..	..	..	..	..	..	..
492	?	L.	..	..	..	..	..	..	..	292·3	292·0	..	..	..	..	..	..	..	..	..	..
496	♂	L.	..	..	..	..	..	..	..	305·0	299·3	..	..	..	..	..	..	..	..	..	..
509	♀	R.	..	..	..	351·4	345·0	331·3	..	299·4	295·8	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	347·2	340·2	328·2	..	..	..	..	..	..	..	..	..	..	..	..	..
511	♀	L.	451·0	443·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
512	?	R.L.	..	..	..	*l* 345·5	..	*r* 326·0	..	..	..	..	..	..	..	..	..	..	..	..	..
528	♀	R.L.	*r* 415·5	*r* 413·4	..	..	..	..	..	*l* 293·0	*l* 287·2	*l* 213·5	*l* 202·0	*l* 240·2	*l* 234·5	*r* 140·0	..	..	..	..	..
544	?	L.	..	..	..	388·2	377·5	363·0	..	325·8	320·1	..	..	..	..	..	..	..	..	..	..
550	?	R.	..	..	..	..	..	..	..	294·5	291·3	..	..	..	..	..	..	..	..	..	..
560	?	L.	418·2	415·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
569A	♀	R.	427·0	423·2	..	..	..	..	..	..	..	..	..	250·5	244·5	126·8	..	..	..	..	..
		L.	..	..	..	..	..	..	..	290·2	288·7	227·5	216·5	248·4	242·4	128·3	..	..	..	..	..
569B	♂	R.L.	..	..	..	*r* 403·8	*r* 394·5	*r* 379·4	..	*l* 332·0	*l* 326·0	..	..	*r* 282·1	*r* 276·2	..	..	..	..	..	..
572	♀	R.	..	..	..	376·5	368·0	356·0	..	331·2	327·0	..	..	273·0	266·6	..	..	..	..	..	..
		L.	..	..	..	373·5	362·2	351·0	..	..	..	246·5	235·0	271·0	265·5	..	..	..	..	..	..
577	♂	R.	501·3	499·0	..	437·0	425·0	406·8	..	..	..	..	..	..	..	172·0	101·0	124·0	..	..	..
		L.	501·1	497·9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
586	?	R.	..	..	..	..	..	359·8	..	..	..	..	..	256·0	251·3	..	..	..	..	..	..
		L.	450·0	443·2	..	385·4	376·0	364·0	..	..	..	235·2	224·2	..	..	..	..	..	..	..	..
598	♂	R.	466·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	470·0	464·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Q GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth.	Length.	Breadth.	Infra-spinous length.
601	?	R.	..	..	..	..	..	351·4	..	311·0	309·0	..	..	..	..	..	..	..	..	..	..
607	?	R.	..	..	..	..	..	..	379·0	..	..	..	..	..	..	..	..	..	..	..	..
610	♀	R.L.	*l* 395·3	*l* 392·0	*l* 59·5	*l* 364·0?	*l* 355·3?	*l* 344·0?	..	*r* 294·6	*r* 290·2	..	..	..	..	..	..	..	..	..	..
615	?	R.	..	..	..	..	..	..	..	..	..	237·9	226·6	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	297·8	295·6	238·4	225·7	..	250·7	..	..	..	..	..	..
631	♀	R.	422·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	423·2	417·3	63·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
656	?	R.	..	..	..	350·5	342·0	327·0	343·9	..	..	..	..	..	..	..	..	..	..	..	..
		L.	422·0	417·6	..	350·3	342·0	326·5	..	..	..	..	..	..	..	..	..	..	..	..	..
666	?	—	..	..	..	..	..	..	..	..	..	..	..	..	..	..	89·4	108·8	..	..	..
673	♂	R.	407·0	405·1	67·9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	410·9	407·1	..	335·6	327·7	315·0	..	..	..	..	..	..	..	..	..	..	..	..	..
686	♀	R.	382·3	377·5	..	..	..	..	..	263·0	261·3	..	..	..	..	119·0	86·3	98·3	..	..	..
		L.	..	..	..	..	..	..	..	256·2	253·5	..	..	..	..	119·4	..	..	..	..	..
686A	?	L.	423·8	420·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
693	?	R.	414·2	406·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
766	?	R.	..	..	..	363·8	353·7	340·2	..	..	..	233·0	219·5	258·6	254·0	..	..	..	..	..	..
		L.	431·1	425·2	..	361·5	351·2	338·5	..	..	..	..	..	256·0	252·0	..	..	..	..	..	..
797	♀	R.	363·4	360·5	..	..	..	..	..	272·4	270·0	..	..	..	..	131·1	..	..	..	..	..
		L.	..	..	..	..	..	..	..	266·3	263·4	..	..	227·0	224·0	..	..	..	..	..	..
806	♂	R.	460·0	455·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	461·1	458·4	..	393·0	383·5	367·0	..	..	..	..	..	..	..	..	..	..	..	..	..
865	♀	R.	383·0	..	..	310·0	301·8	289·0	..	268·8	265·9	..	..	227·3	222·4	123·7	..	..	..	..	..
		L.	383·0	382·0	60·0	313·0	305·2	292·0	..	262·1	257·6	..	..	226·6	220·6	123·7	..	..	..	..	..
908	?	R.	..	..	..	390·4	380·1	363·3	..	..	..	..	..	..	..	..	..	..	..	..	..

Q GRAVES.—*Non-skeletons.*

Q (bones without numbers). F.r. 469·3, 467·9; 447·2, 440·8. F.l. 482·4, ——; 468·0, 464·8; 447·0, 443·2. T.r. 366·4, 357·8, 344·3; 346·0, 338·3, 323·0. T.l. 369·2, 359·5, 346·8. H.r. 352·8, 352·4; 312·4, 312·0; 308·0, 303·6; 294·2, 292·3. H.l. 296·6, ——. R.l. 263·0, 249·8; 259·0, 250·0. U.r. 248·0, 243·3. U.l. ——, 277·0; ——, 232·5. Sacrum 101·0, 111·5.

Q 83. T.r. ——, ——, 374·0.
Q 109. F.l. 426·4, 423·0.
Q 176B. F.l. 466·0, ——.
Q 212. U.l. ——, 276·3.
Q 212–1. R.l. ——, 246·8; Cl.l. 158·1.
Q 252. H.l. 299·8, ——.
Q 324. H.l. 296·0, 292·0.

Q 359–3. F.r. 448·0, 442·3; F.l. 451·6, 445·8.
Q 377. T.l. 381·3, 371·0, 358·5; Sacrum 116·0, 111·3.
Q 482. F.l. 449·0, 445·2, 74·5.
Q 528. F.r. 415·5, 413·4.
Q 598. F.l. 472·3, 471·4.

B Graves.—*Skeletons.*

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length
2	♂	R.	419·5	412·0	..	349·3	341·5	329·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	422·3	415·3	..	354·0	347·0	334·5	..	..	..	..	..	..	..	..	..	..	..	..	..
2x	♂	R.	447·8	446·5	76·2	376·0	366·3	351·2	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	445·3	445·0	..	374·4	364·8	349·3	..	?300·2	?300·1	..	..	..	..	..	..	..	..	..	..
3	?	R.	..	..	..	370·2	358·8	342·0	..	..	..	..	..	..	..	..	..	..	..	..	..
4	?	L.	..	..	..	378·3	371·8	358·0	..	..	..	..	..	..	..	..	..	..	..	..	..
5	♂	R.	..	..	..	392·0	381·8	364·6	..	315·3	312·0	253·3	241·0	..	..	..	..	..	..	..	..
		L.	..	..	..	391·7	382·0	366·2	..	314·0	307·1	..	..	277·0	273·4	..	..	..	..	..	..
8	♂	R.	..	..	..	391·4	384·0	370·7	..	..	..	..	..	..	..	..	104·0	104·3	..	..	..
		L.	442·2	441·0	69·1	370·3	357·3	342·6	354·5	..	..	247·2	233·0	261·3	258·6	..	..	..	..	..	..
9	?	R.	..	..	..	362·0	352·2	337·8	347·5	..	..	..	..	..	..	..	..	..	..	..	..
10	♂	L.	478·3	476·0	..	411·0	400·0	384·2	..	..	..	..	..	..	..	..	..	..	..	..	..
12	♂	R.L.	r 451·8	r 445·4	..	l 392·0	l 382·0	l 366·0	l 359·8	..	..	l 260·4	l 248·0	r 279·0	r 273·0	..	93·2	109·6	..	125·0	111·0
12*b*	?	R.	444·5	441·8	..	379·8	370·2	355·7	..	..	..	..	..	..	..	..	..	..	..	..	..
14	♀	R.	436·0	433·2	64·2	367·1	358·6	345·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	437·0	435·5	64·5	373·8	364·3	351·3	..	..	..	233·6	221·2	..	..	..	..	..	..	..	..
15*a*	?	R.	480·3	479·4	72·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
15*ab*	♂	R.	..	..	..	418·0	409·2	392·0	..	..	..	270·2	255·3	288·0	281·2	..	101·3	117·3	..	..	..
		L.	..	..	..	417·0	407·1	392·0	..	338·3	336·8	269·8	254·8	..	..	..	..	..	..	..	..
18	♀	R.	407·7	403·0	62·8	..	..	321·3	..	..	..	..	..	..	235·2	..	..	..	..	..	..
		L.	409·3	405·2	62·0	345·0	335·0	322·8	..	..	..	..	..	233·2	229·2	..	..	..	..	..	..
19	♂	R.	459·8	457·3	79·7	384·3	374·0	358·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	385·0	373·3	357·2	..	..	..	..	..	..	..	..	..	..	..	..	..
21	♀	R.	438·4	432·0	..	363·8	356·0	344·1	..	316·8	314·3	248·2	236·3	..	..	..	..	..	..	..	..
		L.	434·0	427·0	..	..	..	..	..	309·0	306·8	..	..	..	..	..	..	..	..	..	..
22	♂	R.L.	r 500·8	r 499·6	..	l 434·8	l 424·3	l 409·7	..	l 336·4	l 335·3	..	..	..	..	..	105·6	114·7	..	..	..
23*a*	♀	R.	..	..	..	356·8	347·3	333·4	..	300·0	297·4	232·2	220·3	253·1	249·1	..	..	..	..	..	..
		L.	419·2	414·9	..	..	..	..	..	291·0	287·2	..	..	247·2	242·6	..	..	..	..	..	..
24D	?	L.	..	..	..	..	..	..	..	319·5	315·4	..	..	..	..	..	..	..	..	..	..
27	?	R.	..	..	..	382·9	373·7	363·0	..	..	..	..	..	..	..	..	..	..	..	..	..
29	?	R.	..	..	..	359·0	349·5	339·4	..	..	..	..	..	..	..	..	..	..	..	..	..
30	♂	R.	..	..	..	..	..	..	..	..	..	253·2	240·0	..	270·3	148·3	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	..	..	..	..	149·4	..	..	..	..	..
31	♂	R.L.	..	..	..	..	..	..	l 394·0	l 340·0	l 331·4	l 268·0	l 260·8	..	..	r 161·0	..	..	..	..	..

B GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
34	♀	R.	..	..	..	..	..	..	..	299·3	294·1	238·4	226·5	255·8	253·4	..	..	..	..	..	..
		L.	..	..	..	364·5	355·8	343·0	..	..	..	..	..	250·4	247·7	..	..	..	..	..	..
35	♀	R.	436·0	433·8	..	370·5	363·2	350·6	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	432·3	430·8	66·3	..	..	348·2	..	..	..	..	..	..	..	..	..	..	..	..	..
36	♀	R.	449·8	443·8	66·0	363·2	353·3	338·3	350·2	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	366·0	356·2	341·3	354·3	289·0	286·5	..	..	258·3	254·0	..	..	..	..	..	..
37	♀	R.	415·0	411·0	64·4	356·0	346·0	333·0	..	..	..	236·0	223·0	..	..	..	..	..	..	..	..
		L.	417·0	413·0	63·1	..	..	332·0	347·0	290·8	288·2	..	..	..	..	..	..	.	..	..	..
38	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	144·7	89·3	114·8
39	♀	R.	..	..	..	338·0	330·0	316·5	..	283·0	279·2	..	..	..	..	141·2	..	..	..	..	..
		L.	..	..	..	..	..	..	..	279·0	274·0	220·8	210·7	..	..	..	..	..	..	..	..
44	?	R.	428·3	423·5	..	367·2	358·4	343·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	429·8	425·6	..	367·3	358·1	343·7	..	290·0	289·4	..	..	..	..	..	..	..	..	..	..
47	♂	R.	..	..	..	..	..	..	..	321·5	316·2	..	..	..	..	..	87·0	104·4	..	96·4	119·4
48	♂	R.	..	..	..	428·0	416·4	398·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	398·0	..	339·5	335·2	..	..	..	..	..	..	..	..	..	..
49	♂	R.	473·0	468·9	..	..	..	..	..	322·3	317·5	..	..	..	..	147·0	..	..	..	..	..
		L.	478·5	476·0	..	416·3	406·5	389·8	..	323·4	317·2	..	..	285·0	282·0	..	..	..	..	..	..
50*a*	♀	R.	..	..	..	..	..	322·7	339·2	290·4	289·0	..	..	..	..	..	..	..	..	..	..
		L.	428·0	422·6	69·1	347·0	338·0	324·5	339·7	..	..	218·4	206·0	242·0	237·3	..	..	..	..	..	..
50*c*	♀	R.	428·0	424·8	63·0	367·2	356·1	342·0	..	288·1	288·1	233·0	217·0	..	..	142·2	..	..	..	..	..
		L.	422·0	419·8	..	364·7	353·7	340·2	..	283·2	282·7	229·5	213·7	256·1	249·5	143·8	..	..	..	..	..
51	♀	R.	434·9	428·2	63·6	..	..	..	354·1	..	..	..	..	..	..	..	..	..	..	..	..
		L.	436·5	432·2	64·7	366·0	357·0	345·0	..	..	..	..	..	..	..	..	..	..	..	..	..
53	♀	R.	403·3	402·8	62·8	336·0	326·5	313·4	..	288·6	287·0	..	..	..	..	130·1	..	..	..	..	..
		L.	403·4	403·8	66·0	341·2	330·9	319·4	329·0	288·3	288·0	227·0	215·3	..	..	..	..	..	..	..	..
61	?	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	164·0	..	..	..	..	..
62	?	R.	433·4	430·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
67	♀	R.	424·8	420·2	65·5	367·0	358·8	344·7	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	368·2	360·3	347·2	360·2	..	..	..	..	..	..	..	..	..	..	..	..
70	♀	R.	..	..	..	377·2	369·0	355·0	..	..	..	..	235·8	..	..	..	..	..	..	..	..
		L.	..	..	..	379·9	370·5	357·3	..	..	..	..	..	..	..	..	..	..	..	..	..
72	♂	R.L.	*l* 460·0	*l* 460·3 (−)	..	*r* 399·5	*r* 389·4	*r* 372·2	..	..	..	..	..	..	..	..	..	..	..	..	..
73	?	R.	..	..	..	363·0	350·8	333·5	..	..	..	..	..	..	..	..	..	..	..	..	..

B GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicl.	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
73	?	L.	..	..	..	..	..	433·8	350·3	293·9	292·8	..	..	..	..	..	..	..	..	..	..
74	♂	R.	468·0	465·2	..	405·1	393·0	377·3	..	..	..	..	..	..	..	..	92·3	109·7	..	..	..
		L.	475·8	474·6	..	410·0	398·3	383·2	392·6	..	..	..	..	..	..	..	..	..	..	..	..
76	♀	R.	..	..	..	341·3	331·1	314·9	..	..	..	231·0	216·4	254·0	246·3	..	105·0	107·2	..	..	..
		L.	422·0	416·6	64·3	340·0	328·9	314·0	..	..	..	229·0	214·0	251·0	242·4	..	..	..	..	..	..
77	♀	R.	..	..	..	..	..	..	..	279·5	279·0	..	..	234·0	229·0	..	..	..	..	..	..
		L.	396·3	394·8	55·4	334·0	324·1	312·1	..	..	..	..	..	229·8	226·0	..	..	..	..	..	..
78	♀	R.	402·3	398·2	58·7	..	..	317·7	..	..	..	220·5	209·4	243·0	238·4	..	94·5	111·1	..	..	..
		L.	405·2	400·8	58·6	342·0	331·9	319·0	..	279·0	278·0	221·0	209·0	242·1	239·7	..	..	..	..	..	..
80	?	R.	..	..	..	390·2	380·9	366·4	..	..	..	..	..	..	..	..	..	..	..	..	..
83	♂	L.	..	..	..	..	..	..	382·6	..	..	..	..	..	..	..	..	..	..	..	..
84	♂	R.	436·8	431·0	..	363·6	354·2	339·0	351·0	308·3	304·2	..	..	..	..	..	..	..	..	..	..
		L.	438·0	432·4	62·6	367·7	359·0	344·0	..	..	..	..	..	..	..	..	..	..	..	..	..
86	♂	R.	..	..	..	..	..	..	..	320·0	319·0	257·0	242·8	..	..	149·0	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	253·0	237·0	274·0	268·0	..	..	..	..	..	..
90	♀	R.	..	..	..	361·8	354·2	339·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	362·5	354·2	339·5	..	277·4	275·8	..	..	..	..	..	..	..	..	..	..
94	♀	R.	465·0	461·0	..	..	..	376·2	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	401·5	392·0	376·5	..	326·3	322·3	..	..	..	261·0	..	..	..	..	..	..
95	?	R.	..	..	..	397·3	389·0	375·3	..	..	..	..	..	..	..	..	..	..	..	..	..
97	?	L.	..	..	..	..	..	..	..	272·2	271·1	..	..	..	..	..	..	..	..	..	..
100	♀	R.	422·2	418·5	63·6	363·0	355·0	342·3	..	..	..	232·5	222·3	255·2	250·4	138·4	..	..	..	..	..
		L.	..	..	..	364·0	355·5	342·2	..	297·0	295·2	234·1	223·0	..	..	..	..	..	..	..	..
105	?	L.	..	..	..	361·0	350·6	332·0	..	..	..	..	..	..	..	..	..	..	..	..	..
105A	?	R.	..	..	..	..	..	..	406·5	..	..	255·3	241·7	..	..	..	..	..	..	..	..
106	♂	R.	459·3	..	..	389·3	380·0	364·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	457·2	456·0	70·9	391·2	381·0	366·2	..	323·0	322·0	255·0	239·1	..	..	162·4	..	..	..	..	..
107	?	R.	..	..	..	380·2	370·4	357·0	363·5	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	388·7	379·2	362·3	367·0	317·2	316·3	..	..	..	..	..	..	..	..	..	..
108	♀	R.	402·6	396·3	61·5	348·7	342·0	329·3	332·1	..	..	230·2	217·2	..	..	..	..	..	..	..	..
		L.	402·4	397·2	59·7	353·7	344·7	332·3	..	292·6	291·3	..	..	248·0	245·0	137·8	..	..	..	..	..
109	♀	R.	..	..	..	372·4	364·2	350·2	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	374·0	364·2	350·0	359·3	..	..	..	..	..	..	..	..	..	..	..	..
110	♂	R.	..	..	..	391·0	381·3	369·0	..	332·5	329·7	..	..	285·3	280·4	..	..	..	..	..	..

B GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
110	♂	L.	450·1	448·2	70·2	392·3	382·0	369·2	..	334·4	333·0	262·0	248·5	284·0	278·7	161·2	..	..	..	..	..
111	♀	R.	..	..	..	..	..	..	352·0	300·2	297·1	240·0	227·2	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	353·6	291·6	290·0	236·3	224·0	258·6	251·0	..	..	..	..	..	..
112	♀	R.	399·0	392·0	..	339·4	331·0	317·8	322·0	279·0	278·1	..	..	244·0	236·7	..	103·9	98·8	..	..	..
		L.	392·6	385·1	60·0	338·0	330·2	317·5	..	271·8	271·1	217·0	204·5	242·1	233·8	123·4	..	..	..	..	..
113	♂	R.	477·8	472·0	..	418·0	408 7	392·3	..	340·7	331·0	270·4	257·5	293·8	290·3	..	..	..	174·2	99·6	133·0
		L.	..	..	..	416·0	405·0	391·0	..	337·0	327·3	267·3	254·0	290·3	286·0	..	..	..	168·0	101·3	127·3
114	♂	R.	..	..	..	..	..	..	..	309·7	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	333·2	..	300·9	299·2	238·3	225·4	264·0	258·0	135·4	..	..	147·3	95·0	112·8
115	♂	R.	453·0	452·4	67·4	383·2	374·3	360·3	..	319·0	317·8	249·3	235·6	275·0	269·0	151·1	..	..	..	106·1	107·5
		L.	..	..	..	..	..	..	..	313·0	310·9	..	..	..	..	151·0	..	..	..	..	..
116	♀	R.	415·0	..	..	352·5	344·3	332·3	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	417·0	410·9	59·9	354·2	344·3	333·0	..	..	..	..	..	..	..	..	..	..	..	..	..
117	♀	R.	..	..	..	..	..	..	341·1	290·8	289·7	..	..	..	..	..	92 0	103·9	..	..	..
		L.	..	..	..	..	..	..	347·2	286·0	285·3	..	..	..	..	..	..	..	..	..	..
118	♀	R.	450·3	449·3	81·3	382·5	372·8	359·5	..	341·2	340·2	259·4	245·4	..	..	..	..	..	..	..	..
		L.	460·5	459·0	..	385·7	375·8	363·5	..	..	..	..	..	..	..	..	..	..	..	..	..
119	?	L.	..	..	..	..	..	..	..	287·0	284·2	..	..	..	..	..	..	..	..	..	..
119A	♀	R.	..	..	..	..	..	..	..	290·7	288·1	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	..	..	237 8	226·5	..	..	..	..	..	..	..	..
119*b*	♂	R.	477·8	473·3	75·6	397·0	388·0	373·2	..	332·2	331·6	258·0	242·0	..	276·5	149·3	..	..	..	..	..
		L.	..	..	..	..	..	..	..	329·0	324·8	..	..	277·8	273·2	..	..	..	..	..	..
119*c*	♀	R.	..	..	..	357·0	349·5	334·2	..	..	..	226·3	212·5	250·4	242·1	123·6	..	..	..	..	..
		L.	437·0	435·0	..	356·3	346·7	333·0	..	299·0	297·3	..	..	247·3	241·0	..	..	..	131·0	89·8	105·0
120	♀	R.	430·5	428·0	..	355·0	347·0	334·6	339·5	..	..	222·1	210·5	247·6	243·4	..	97·6	98·3	..	..	..
		L.	431·3	429·0	60·5	360·3	352·1	340·0	346·3	?309·0	?306·2	217·8	207·0	242·3	238·2	137·5	..	..	..	88·6	101·8
121	♀	R.	..	..	..	372·0	363·1	347·8	..	300·0	297·0	..	..	..	..	132·7	91·2	110·0	..	90·8	106·9
		L.	?412·2	?407·0	..	367·0	359·4	345·3	..	291·5	289·2	235·2	223·2	260·3	253·0	134·2	..	..	..	..	..
122	?	R.	432·2	426·3	..	..	..	..	..	..	..	242·0	238·0	..	260·4	143·7	..	..	..	..	..
		L.	427·0	424·4	..	361·0	350·6	337·2	..	..	..	..	..	259·3	253·0	..	..	..	..	..	..
128	♀	R.	431·0	420·0	63·8	360·2	352·2	338·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	434·6	429·3	..	362·3	352·8	340·3	351·4	296·8	296·2	..	..	..	..	..	..	..	..	..	..
130	♀	R.	438·2	432·0	64·5	367·9	358·3	344·0	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	..	..	..	365·4	357·0	343·0	..	..	..	..	..	..	..	..	..	..	..	..	..

B Graves.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
131	♂	R.	453·1	451·9	71·6	396·0	386·7	374·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	454·0	453·3	..	394·0	385·2	372·3	377·5	327·0	325·3	256·0	242·1	..	269·8	142·8	..	..	..	..	..
132	♂	R.	..	..	..	397·8	389·0	375·3	..	..	..	276·8	261·0	..	..	143·2	..	..	..	99·6	117·0
		L.	457·8	455·5	..	399·9	390·2	377·6	..	..	..	..	..	294·0	290·3	153·2	..	..	..	..	..
133*a*	?	?	..	..	..	400·0	390·8	376·8	..	..	..	..	..	..	..	..	..	..	..	..	..
134	?	R.	..	..	..	397·8	387·7	372·4	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	472·7	468·0	67·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

B Graves.—*Non-Skeletons.*

B. T.r. 397·5, 386·3, 374·0; T.l. 399·0, 390·5, 374·0.

B 2. F.l. 476·0, ——.

B 12. T.l. 365·0, 353·7, 338·0. H.r. 342·0, 338·8. H.l. 316·4, 313·0; 304·5, 303·2. R.l. 250·3, 235·5.

B 21. H.l. 294·5, 293·6.

B 83. F.r. 448·5, 446·0, 68·6; 447·8, 447·1. F.l. 455·3, 454·9, 69·9; 445·3, 443·2, 67·0. T.r. 393·6, 383·2, 368·0. T.l. 394·2, 382·3, 368·0, 377·0, 367·6, 353·2.

B 86. F.r. 461·3, 456·2, 70·9; 458·3, 455·1. F.l. 463·3, 461·4, 70·7; 462·0, 458·3, 73·6. T.r. 408·0, 398·6, 383·7; 392·3, 384·2, 371·0. T.l. 406·2, 398·0, 384·0; 394·0, 386·4, 372·3.

B 90. F.r. 410·6, 408·2, 61·4; F.l. 409·1, 406·0, 63·5.

B 105. F.l. 523·4, 521·0; 498·1, 493·5. T.r. 363·9, 354·0, 335·0. T.l. 425·0, 414·6, 399·1.

B 105A. T.r. 420·8, 411·3, 396·2.

B 107. F.r. 437·2, 435·0; F.l. 439·5, 436·2, 68·5.

B 111. F.r. 453·4, 447·5, 61·0. F.l. 452·3, 448·3, 59·1; 417·5, 413·3, 63·0. T.r. 376·0, 368·0, 355·1; 358·0, 351·4, 336·8. T.l. 381·3, 372·4, 360·4; 354·7, 348·3, 334·8.

B 117. T.r. 353·4, 344·3, 333·3; 349·8, 342·8, 330·8. T.l. 354·8, 346·7, 336·0.

T GRAVES.—*Skeletons.*

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maxi-mum.	Ob-lique.	Neck.	Maxi-mum.	Ex-cluding spine.	Centre to centre.	Maxi-mum.	Maxi-mum.	Ob-lique.	Maxi-mum.	Centre to centre.	Maxi-mum.	Ex-cluding styloid.	Maxi-mum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
2	?	R.L.	..	..	..	..	..	..	..	r342·5	r340·9	l260·5	l246·0	..	..	r177·0	..	..	..	..	..
4c	♂	R.	426·8	425·7	68·8	371·1	364·0	351·0	358·0	..	..	246·5	231·0	272·2	263·0	..	..	..	..	..	..
		L.	426·2	425·2	71·4	367·8	359·0	346·5	357·0	..	..	..	..	..	..	..	..	..	..	..	..
5E	♀	R.	444·6	440·8	57·2	375·0	367·0	352·8	362·0	296·2	292·0	240·3	229·3	..	..	144·2	..	..	..	91·8	95·0
		L.	444·8	441·0	62·9	378·0	371·2	357·0	..	291·1	285·0	239·5	228·0	260·2	254·0	..	..	..	..	94·2	97·1
5F	♀	L.	..	..	..	..	..	..	..	..	..	..	..	272·0	269·2	..	..	..	..	..	..
6	♀	L.	..	..	..	347·0	337·4	326·2	..	..	..	..	..	250·0	247·6	..	101·1	107·4	..	..	..
7	♀	R.	385·0	384·0	60·2	..	..	..	307·0	..	..	216·0	204·4	..	..	..	..	..	..	..	..
		L.	..	..	..	333·4	323·5	311·2	..	288·2	284·3	..	..	..	234·8	..	..	..	..	..	..
10	♂	R.	..	..	..	..	..	400·8	..	346·3	341·8	..	260·0	288·9	285·0	169·0	..	..	..	110·3	119·4
		L.	496·2	489·8	77·1	..	..	401·5	406·0	346·2	342·4	..	261·0	..	..	161·2	..	..	..	111·3	121·5
15	♂	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	161·2	..	..	..	..	..
15E	?	R.	462·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	487·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
16	♀	R.	433·2	430·4	66·1	361·2	350·9	336·0	348·0	301·8	299·3	237·0	222·3	257·0	250·0	..	100·3	115·8	..	..	..
		L.	438·2	434·2	67·3	359·8	349·0	336·8	352·0	297·1	295·7	235·0	219·8	254·3	249·0	148·0	..	..	..	95·3	100·9
17	♀	R.L.	r428·0	r424·3	r64·5	r356·0	r346·0	r332·5	..	l289·3	l286·9	r226·2	r214·5	..	l241·8	..	93·2	109·8	..	..	..
18	♀	R.	..	..	..	..	..	..	..	312·2	312·2	234·5	221·7	..	..	..	97 8	117·5	..	..	..
		L.	..	..	..	..	..	..	..	304·2	304·2	..	..	251·3	247·4	145·0	..	..	..	..	..
19	♂	R.	428·3	427·2	71·1	366·0	358·2	345·0	361·8	303·2	302·8	..	..	273·2	265·7	..	93·3	111·2	..	..	..
		L.	423·5	421·2	69·5	365·0	356·4	342·5	..	293·8	293·0	245·4	233·0	270·2	262·5	..	..	..	..	..	..
20	♀	L.	..	..	..	343·3	334·0	322·0	..	..	..	..	..	..	..	..	..	..	..	..	..
21	♂	R.	463·6	..	..	379·0	367·8	355·8	..	..	..	..	..	..	..	155·6	..	..	150·4	99·0	112·2
		L.	..	..	..	..	..	..	367·0	..	..	..	..	..	..	..	..	..	150·2	101·3	113·8
25	?	R.	..	..	..	..	..	..	..	..	..	..	..	270·5	266·0	..	..	..	..	..	..
26	♂	R.	472·3	469·0	..	402·0	391·8	377·0	382·5	..	..	..	..	..	..	..	..	..	..	..	..
		L.	471·8	469·8	..	404·4	395·8	381·2	..	..	..	..	..	..	..	..	..	..	..	..	..
29	♀	R.	..	..	..	..	..	..	..	289·0	..	228·0	216·0	..	..	..	..	..	..	..	..
30	♂	R.	503·0	499·5	..	415·4	407·6	392·5	399·0	354·0	350·8	284·8	272·0	314·0	308·3	..	..	..	..	..	..
		L.	499·0	497·0	82·9	418·4	408·0	394·8	400·2	347·8	346·8	282·7	269·0	306·5	302·5	..	..	..	..	..	..
35	♀	R.	484·8	479·2	..	407·3	396·6	384·6	394·0	..	..	..	..	..	..	..	..	..	..	..	..
36	♂	R.	457·2	453·3	67·7	..	..	..	372·0	..	..	..	..	..	..	..	..	..	..	..	..
		L.	457·5	454·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
37	♂	R.	..	..	..	..	..	351·3	..	..	..	259·3	244·2	282·8	277·0	164·3	..	..	..	..	..

B Graves.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
131	♂	R.	453·1	451·9	71·6	396·0	386·7	374·5	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	454·0	453·3	..	394·0	385·2	372·3	377·5	327·0	325·3	256·0	242·1	..	269·8	142·8	..	..	..	..	..
132	♂	R.	..	..	..	397·8	389·0	375·3	..	..	..	276·8	261·0	..	..	143·2	..	..	..	99·6	117·0
		L.	457·8	455·5	..	399·9	390·2	377·6	..	..	..	..	..	294·0	290·3	153·2	..	..	..	..	..
133*a*	?	?	..	..	..	400·0	390·8	376·8	..	..	..	..	..	..	..	..	..	..	..	..	..
134	?	R.	..	..	..	397·8	387·7	372·4	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	472·7	468·0	67·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

B Graves.—*Non-Skeletons.*

B. T.r. 397·5, 386·3, 374·0; T.l. 399·0, 390·5, 374·0.

B 2. F.l. 476·0, ——.

B 12. T.l. 365·0, 353·7, 338·0. H.r. 342·0, 338·8. H.l. 316·4, 313·0; 304·5, 303·2. R.l. 250·3, 235·5.

B 21. H.l. 294·5, 293·6.

B 83. F.r. 448·5, 446·0, 68·6; 447·8, 447·1. F.l. 455·3, 454·9, 69·9; 445·3, 443·2, 67·0. T.r. 393·6, 383·2, 368·0. T.l. 394·2, 382·3, 368·0, 377·0, 367·6, 353·2.

B 86. F.r. 461·3, 456·2, 70·9; 458·3, 455·1. F.l. 463·3, 461·4, 70·7; 462·0, 458·3, 73·6. T.r. 408·0, 398·6, 383·7; 392·3, 384·2, 371·0. T.l. 406·2, 398·0, 384·0; 394·0, 386·4, 372·3.

B 90. F.r. 410·6, 408·2, 61·4; F.l. 409·1, 406·0, 63·5.

B 105. F.l. 523·4, 521·0; 498·1, 493·5. T.r. 363·9, 354·0, 335·0. T.l. 425·0, 414·6, 399·1.

B 105A. T.r. 420·8, 411·3, 396·2.

B 107. F.r. 437·2, 435·0; F.l. 439·5, 436·2, 68·5.

B 111. F.r. 453·4, 447·5, 61·0. F.l. 452·3, 448·3, 59·1; 417·5, 413·3, 63·0. T.r. 376·0, 368·0, 355·1; 358·0, 351·4, 336·8. T.l. 381·3, 372·4, 360·4; 354·7, 348·3, 334·8.

B 117. T.r. 353·4, 344·3, 333·3; 349·8, 342·8, 330·8. T.l. 354·8, 346·7, 336·0.

T Graves.—*Skeletons.*

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infraspinous length.
2	?	R.L.	..	..	..	..	..	..	..	*r*342·5	*r*340·9	*l*260·5	*l*246·0	..	..	*r*177·0	..	..	..	..	..
4c	♂	R.	426·8	425·7	68·8	371·1	364·0	351·0	353·0	..	..	246·5	231·0	272·2	263·0	..	..	..	..	..	..
		L.	426·2	425·2	71·4	367·8	359·0	346·5	357·0	..	..	..	..	..	..	..	..	..	..	..	..
5E	♀	R.	444·6	440·8	57·2	375·0	367·0	352·8	362·0	296·2	292·0	240·3	229·3	..	..	144·2	..	..	..	91·8	95·0
		L.	444·8	441·0	62·9	378·0	371·2	357·0	..	291·1	285·0	239·5	228·0	260·2	254·0	..	..	..	..	94·2	97·1
5F	♀	L.	..	..	..	..	..	..	..	..	..	..	..	272·0	269·2	..	..	..	..	..	..
6	♀	L.	..	..	..	347·0	337·4	326·2	..	..	..	..	..	250·0	247·6	..	101·1	107·4	..	..	..
7	♀	R.	385·0	384·0	60·2	..	..	..	307·0	..	..	216·0	204·4	..	..	..	..	..	..	..	..
		L.	..	..	..	333·4	323·5	311·2	..	288·2	284·3	..	..	..	234·8	..	..	..	..	..	..
10	♂	R.	..	..	..	..	..	400·8	..	346·3	341·8	..	260·0	288·9	285·0	169·0	..	..	..	110·3	119·4
		L.	496·2	489·8	77·1	..	..	401·5	406·0	346·2	342·4	..	261·0	..	..	161·2	..	..	..	111·3	121·5
15	♂	R.	..	..	..	..	..	..	..	..	..	..	..	..	..	161·2	..	..	..	..	..
15E	?	R.	462·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	487·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
16	♀	R.	433·2	430·4	66·1	361·2	350·9	336·0	348·0	301·8	299·3	237·0	222·3	257·0	250·0	..	100·3	115·8	..	..	..
		L.	438·2	434·2	67·3	359·8	349·0	336·8	352·0	297·1	295·7	235·0	219·8	254·3	249·0	148·0	..	..	..	95·3	100·9
17	♀	R.L.	*r*428·0	*r*424·3	*r*64·5	*r*356·0	*r*346·0	*r*332·5	..	*l*289·3	*l*286·9	*r*226·2	*r*214·5	..	*l*241·8	..	93·2	109·8	..	..	..
18	♀	R.	..	..	..	..	..	..	..	312·2	312·2	234·5	221·7	..	..	..	97 8	117·5	..	..	..
		L.	..	..	..	..	..	..	..	304·2	304·2	..	..	251·3	247·4	145·0	..	..	..	..	..
19	♂	R.	428·3	427·2	71·1	366·0	358·2	345·0	361·8	303·2	302·8	..	..	273·2	265·7	..	93·3	111·2	..	..	..
		L.	423·5	421·2	69·5	365·0	356·4	342·5	..	293·8	293·0	245·4	233·0	270·2	262·5	..	..	..	..	..	..
20	♀	L.	..	..	..	343·3	334·0	322·0	..	..	..	..	..	..	..	..	..	..	..	..	..
21	♂	R.	463·6	..	..	379·0	367·8	355·8	..	..	..	..	..	..	..	155·6	..	..	150·4	99·0	112·2
		L.	..	..	..	..	..	..	367·0	..	..	..	..	..	..	..	..	..	150·2	101·3	113·8
25	?	R.	..	..	..	..	..	..	..	..	..	..	..	270·5	266·0	..	..	..	..	..	..
26	♂	R.	472·3	469·0	..	402·0	391·8	377·0	382·5	..	..	..	..	..	..	..	..	..	..	..	..
		L.	471·8	469·8	..	404·4	395·8	381·2	..	..	..	..	..	..	..	..	..	..	..	..	..
29	♀	R.	..	..	..	..	..	..	..	289·0	..	228·0	216·0	..	..	..	..	..	..	..	..
30	♂	R.	503·0	499·5	..	415·4	407·6	392·5	399·0	354·0	350·8	284·8	272·0	314·0	308·3	..	..	..	..	..	..
		L.	499·0	497·0	82·9	418·4	408·0	394·8	400·2	347·8	346·8	282·7	269·0	306·5	302·5	..	..	..	..	..	..
35	♀	R.	484·8	479·2	..	407·3	396·6	384·6	394·0	..	..	..	..	..	..	..	..	..	..	..	..
36	♂	R.	457·2	453·3	67·7	..	..	..	372·0	..	..	..	..	..	..	..	..	..	..	..	..
		L.	457·5	454·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
37	♂	R.	..	..	..	..	..	351·3	..	..	..	259·3	244·2	282·8	277·0	164·3	..	..	..	..	..

T GRAVES.—*Skeletons* (continued).

No.	Sex.	Side.	Femur.			Tibia.			Fibula.	Humerus.		Radius.		Ulna.		Clavicle	Sacrum.		Scapula.		
			Maximum.	Oblique.	Neck.	Maximum.	Excluding spine.	Centre to centre.	Maximum.	Maximum.	Oblique.	Maximum.	Centre to centre.	Maximum.	Excluding styloid.	Maximum.	Length.	Breadth	Length.	Breadth	Infra-spinous length.
37	♂	L.	..	..	..	..	..	..	..	326·0	322·0	259·5	244·4	283·0	276·2	..	..	..	..	..	..
39	♀	R.L.	*l* 430·0	..	..	..	..	..	..	*l* 299·5	*l* 296·3	*r* 234·0	*r* 221·8	..	..	..	101·3	105·3	..	..	..
40	♂	R.	474·4	473·2	..	394·0	384·0	371·3	..	..	..	..	..	..	..	..	116·1	114·6	..	..	..
		L.	475·2	472·3	..	394·8	384·9	373·0	382·0	..	..	..	..	..	..	..	..	..	..	..	..
41	♀	R.	..	..	..	..	..	..	380·3	..	..	262·0	249·2	..	..	148·4	99·6	110·4	..	..	..
		L.	..	..	..	..	..	..	382·0	330·3	328·0	262·0	248·1	..	281·1	..	..	..	..	..	..
43	♀	R.	399·2	392·7	61·8	..	..	..	320·8	284·0	282·0	..	..	244·0	240·0	..	..	..	..	..	..
		L.	..	..	..	..	..	..	..	276·3	273·2	..	..	240·3	238·0	..	..	..	..	..	..
52	?	R.	484·0	..	..	402·0	392·0	379·4	390·0	340·2	338·2	..	..	..	..	..	..	..	..	..	..
54	♀	R.	403·1	396·5	..	340·9	332·3	319·0	334·0	290·4	289·0	..	..	..	..	121·4	..	..	..	..	..
		L.	403·7	397·0	..	344·3	334·4	321·3	334·0	284·9	284·0	223·0	210·4	244·1	240·0	..	..	..	..	..	..
55	♀	R.	460·0	455·2	..	388·2	378·6	364·7	370·3	319·5	317·0	249·5	235·0	..	..	..	..	..	..	..	..
		L.	460·0	456·3	..	388·5	378·0	365·5	..	..	..	..	..	..	..	154·9	..	..	..	..	..
56	♀	R.	420·6	416·0	..	364·0	354·2	340·1	349·0	314·0	311·0	..	..	260·5	254·0	..	..	..	137·8	95·2	98·3
		L.	..	..	..	364·0	354·6	341·4	..	306·2	305·2	241·8	230·0	260·7	255·3	..	..	..	..	95·8	96·0
57	♂	R.	464·3	462·0	76·0	392·0	382·5	365·8	372·0	322·6	315·3	241·6	226·8	..	..	156·0	..	..	..	..	..
		L.	..	..	..	392·3	382·4	366·0	374·0	..	..	241·0	225·5	263·2	256·3	..	..	..	..	..	..
58	♀	R.	428·3	424·0	66·6	343·8	333·6	320·6	..	..	..	..	..	..	..	..	..	..	..	..	..
		L.	423·2	418·0	..	346·3	337·0	324·4	333·4	285·1	284·0	..	..	..	..	..	..	..	..	..	..
59	♀	R.	437·0	436·0	65·6	369·3	359·0	343·0	253·2	317·0	313·4	243·2	231·2	269·8	261·0	..	..	..	..	..	..
		L.	443·7	441 2	..	370·0	360·0	345·4	..	310·3	306·3	239·3	225·3	263·0	255·0	..	..	..	137·4	98·9	105·2

T GRAVES.—*Non-Skeletons.*

T 4. F.r. 468·2, 462·4, 75·4. F.l. 470·3, 461·4, 74·7; 446·0, 444·5, 70·5. T.r. 386·0, 377·9, 365·0; 370·5, 363·0, 347·5. T.l. 399·8, 389·4, 374·3; ——, 362·3, 348·2. Fib.l. 379·8; 361·5.

T 17. H.l. 329·0, 326·4.

DESCRIPTION OF PLATE 22.

Figs. 1–6 indicate the various measurements made on the different bones.

Fig. F.l. 235 is the outline of a cross-section through the middle of the shaft of a pilastric femur. It resembles an isosceles triangle, and is the rarer type.

Fig. F.r. 175. This is the commoner type where the crest is rectangular in cross-section.

Fig. F.r. 7 (1). A similar cross-section through a femur with a low pilastric index.

Fig. F.r. 7 (2). A sub-trochanteric section through the same femur, showing the antero-posterior flattening (platymerism), and the third trochanter indicated by *.

Fig. F.r. 1612. A sub-trochanteric section through a less pronounced platymeric femur.

Figs. T.r. T 40 and T.r. 382 are cross-sections through strongly platycnemic tibiæ. In T.r. T 40 the posterior surface has disappeared, while this is not the case in T.r. 382. The sections were taken at the level of the anterior nutritive foramen.

Fig. Fib.l. B 107. Cross-section through a channelled fibula.

Fig. U.r. B 114. An outline of an incurved ulna.

Fig. S. 1102 exhibits the curvature of a sacrum composed of six vertebræ and possessing two promontories owing to the imperfect assimilation of the first vertebra.

Figs. S. 1212 and S.B. 112. These indicate the extremes which were observed in the curvature of the sacrum. S. 1212 is a male sacrum, and S.B. 112 is a female sacrum.

INDEX

TO THE

PHILOSOPHICAL TRANSACTIONS,

SERIES B,

FOR THE YEAR 1897 (VOL. 189).

B.

BOWER (F. O.). Studies in the Morphology of Spore-producing Members.—III. Marattiaceæ, 35.

C

Cheirostrobus, a new Type of Fossil Cone (SCOTT), 1.

E.

Enamel, Tubular, in Marsupials and other Animals (TOMES), 107.

F.

Fossil Plants from Palæozoic Rocks (SCOTT), 1, 83.

L.

Lycopodiaceæ; *Spencerites*, a new Genus of Cones from Coal-measures (SCOTT), 83.

M.

Marattiaceæ, Fossil and Recent, Comparison of Sori of (BOWER), 3
Marsupials, Tubular Enamel a Class Character of (TOMES), 107.

N.

Naqada Race, Variation and Correlation of Skeleton in (WARREN), 135

P.

Pteridophyta: *Cheirostrobus*, a Fossil Cone, &c. (SCOTT), 1.

S.

SCOTT (D. H.). On the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.—On *Cheirostrobus*, a new Type of Fossil Cone from the Lower Carboniferous Strata (Calciferous Sandstone Series), 1.
SCOTT (D. H.). On the Structure and Affinities of Fossil Plants from the Palæozoic Rocks.—II. On *Spencerites*, a new Genus of Lycopodiaceous Cones from the Coal-measures, founded on the *Lepidodendron Spenceri* of WILLIAMSON, 83.
Skeleton, Human, Variation and Correlation of Parts of (WARREN), 135.
Sorus of *Danæa*, *Kaulfussia*, *Marattia*, *Angiopteris* (BOWER), 35.
Spencerites insignis (WILL.) and *S. majusculus*, n. sp., Lycopodiaceous Cones from Coal-measures (SCOTT), 83.
Sphenophylleæ, Affinities with *Cheirostrobus*, a Fossil Cone (SCOTT), 1.
Spore-producing Members, Morphology of.—III. Marattiaceæ (BOWER), 35.
Stereum hirsutum, Biology of; destruction of Wood by (WARD), 123.

T.

TOMES (CHARLES S.). On the Development of Marsupial and other Tubular Enamels, with Notes upon the Development of Enamels in general, 107.

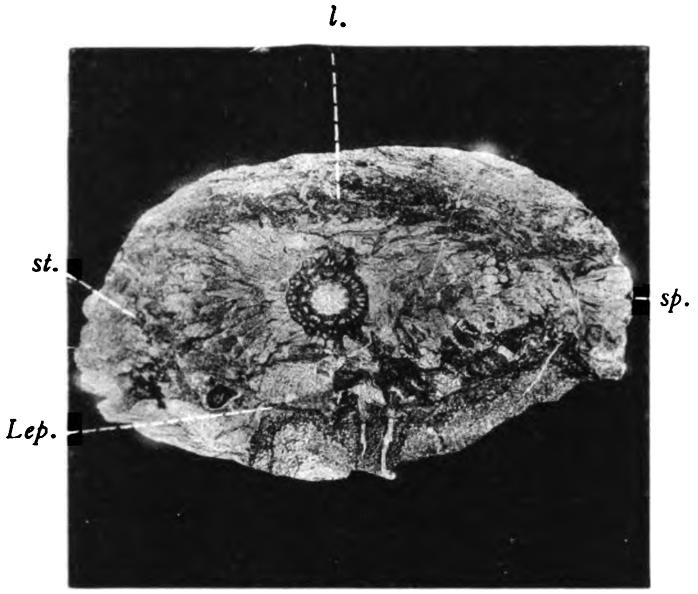
V.

Variability of Human Skeleton (WARREN), 13 .

W.

WARD (H. MARSHALL). On the Biology of *Stereum hirsutum* (FR.), 123.
WARREN (ERNEST). An Investigation on the Variability of the Human Skeleton: with especial reference to the Naqada Race discovered by Professor FLINDERS PETRIE in his Explorations in Egypt, 135.
Wood, piercing of elements, alteration of Cell-walls, and destruction of, by *Stereum hirsutum* (WARD), 123.

HARRISON AND SONS, PRINTERS IN ORDINARY TO HER MAJESTY, ST. MARTIN'S LANE, LONDON, W.C.



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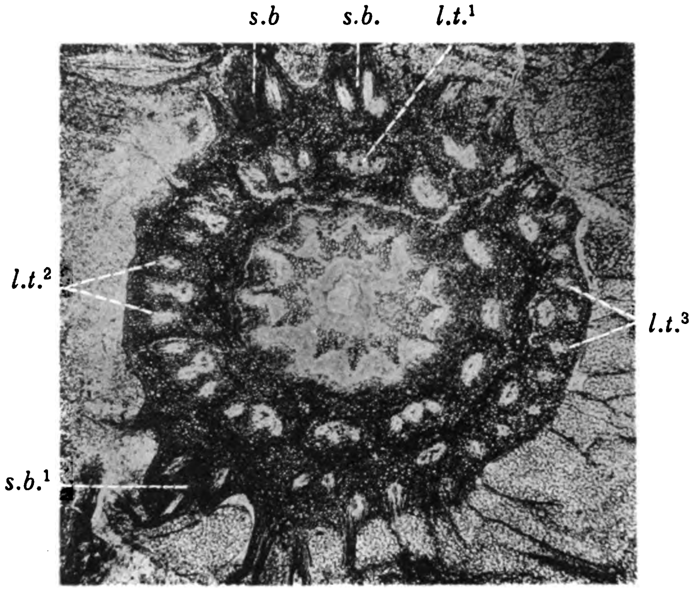

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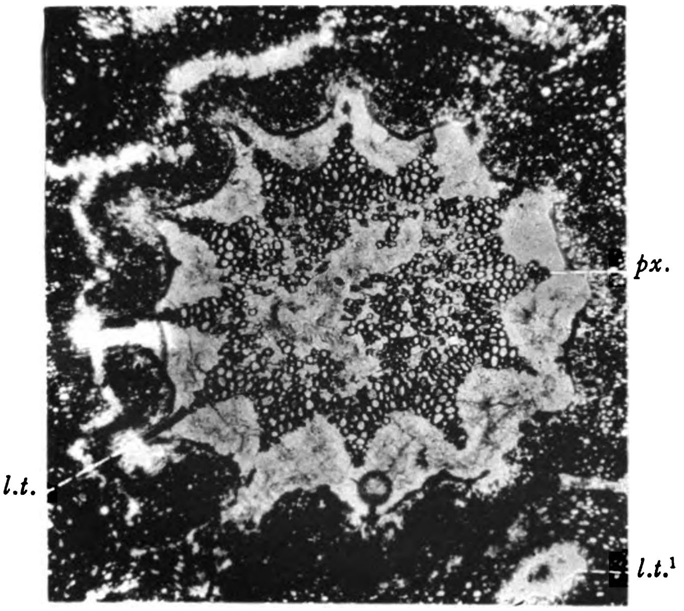

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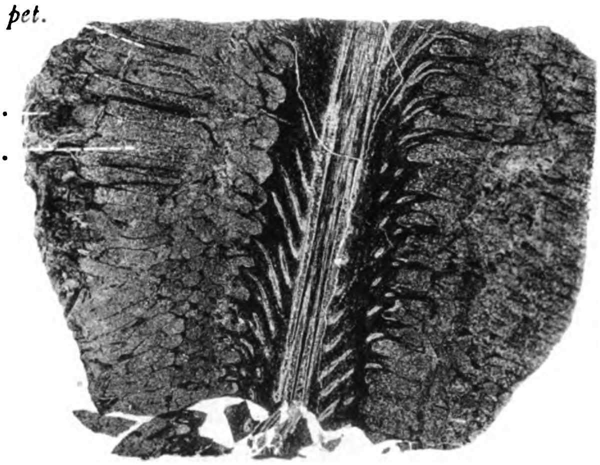

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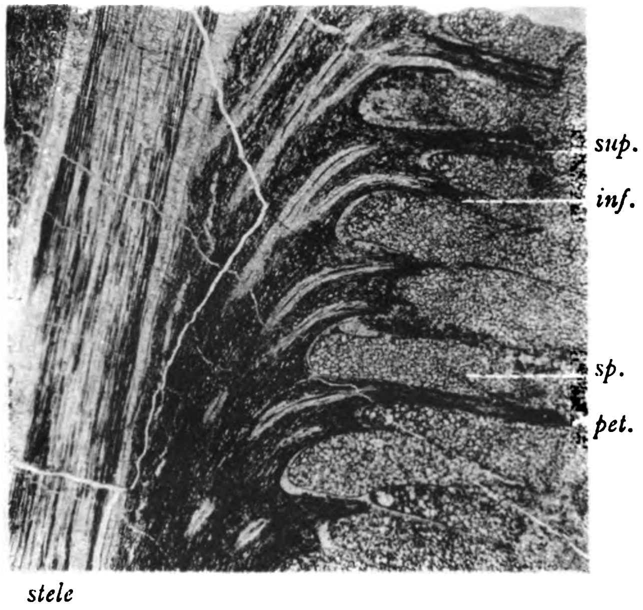

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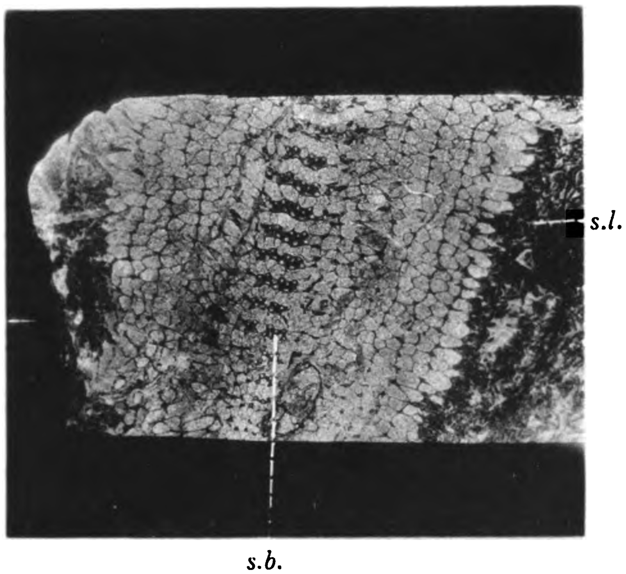

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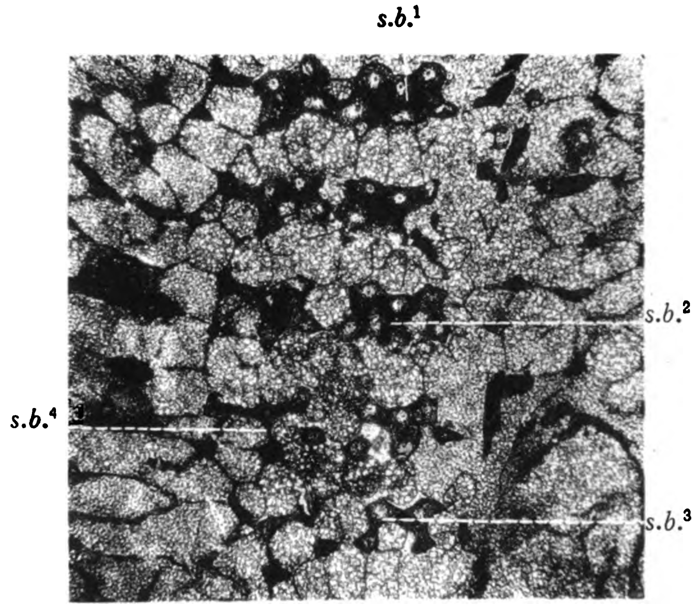
D. H. Scott. *Phil. Trans.* 1897. *B. Plate* 2



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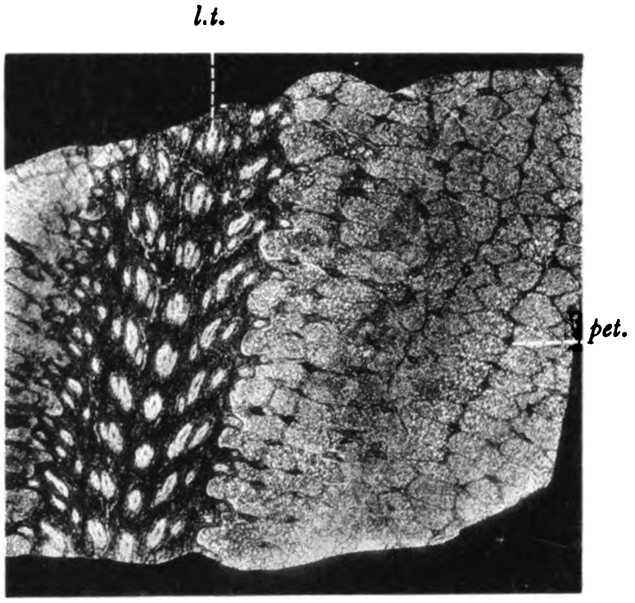

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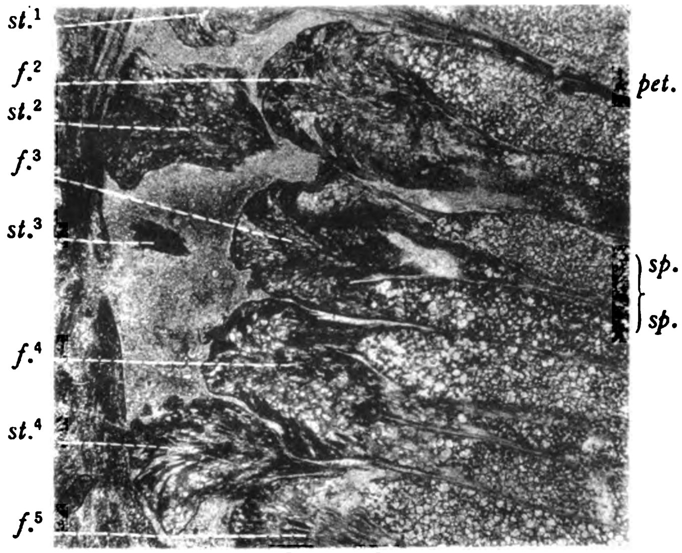

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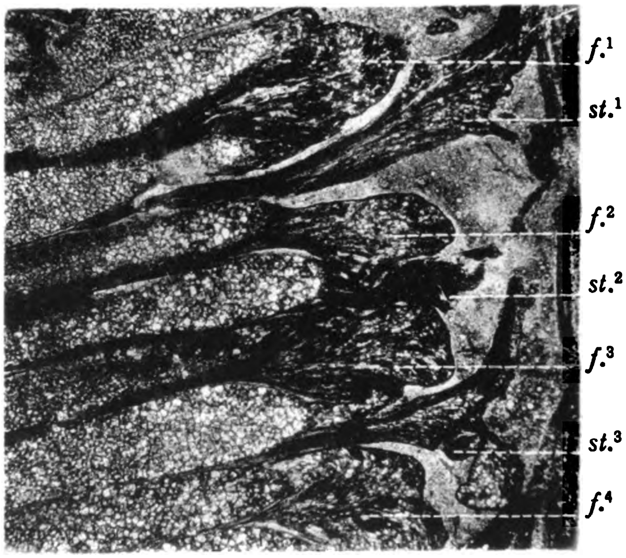

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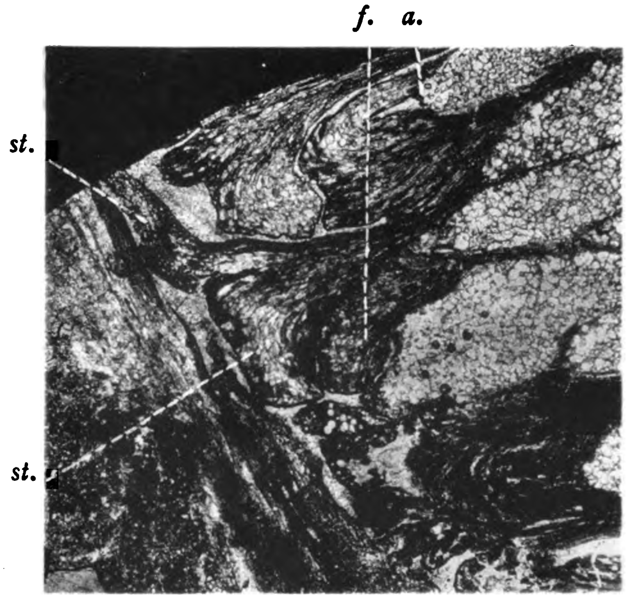

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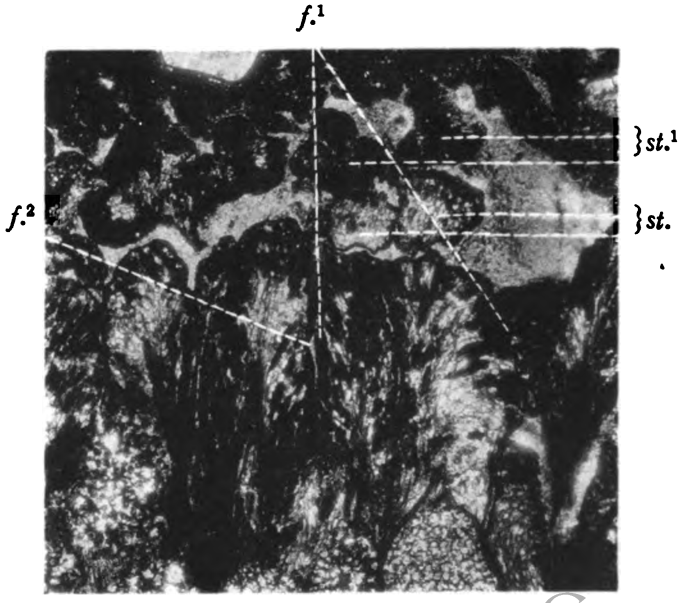

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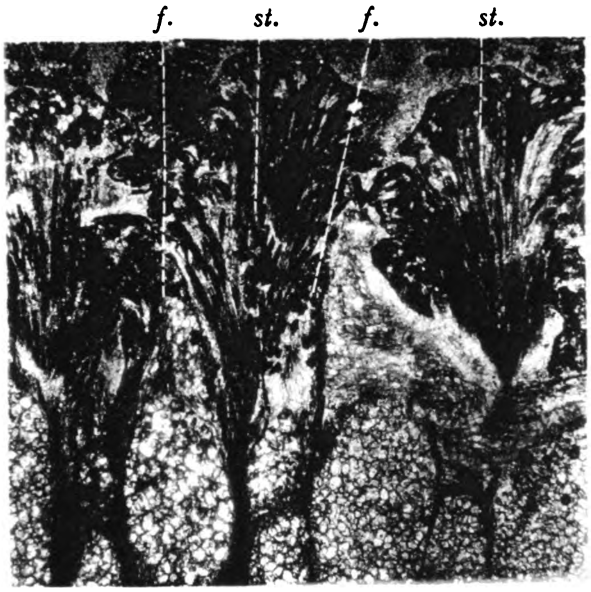

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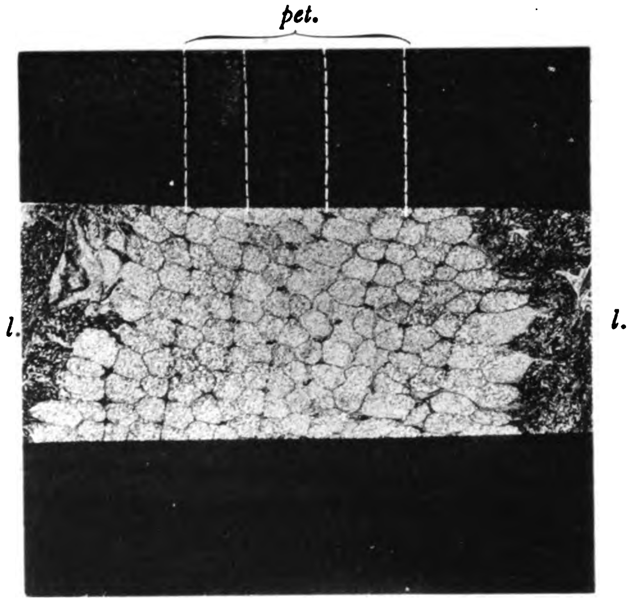

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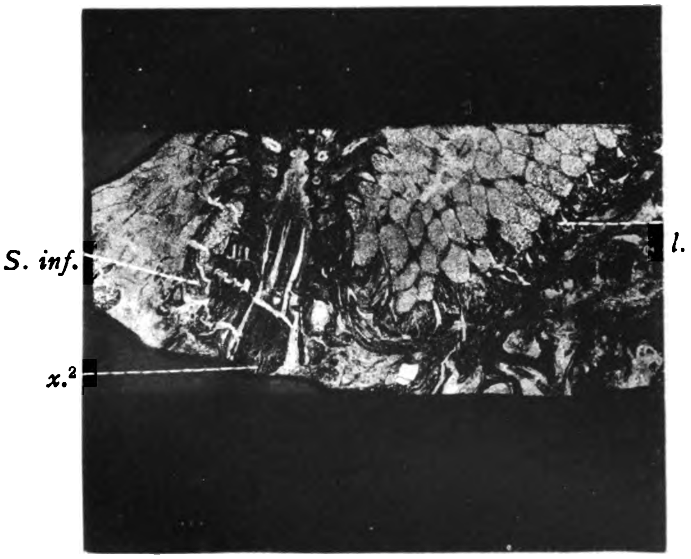

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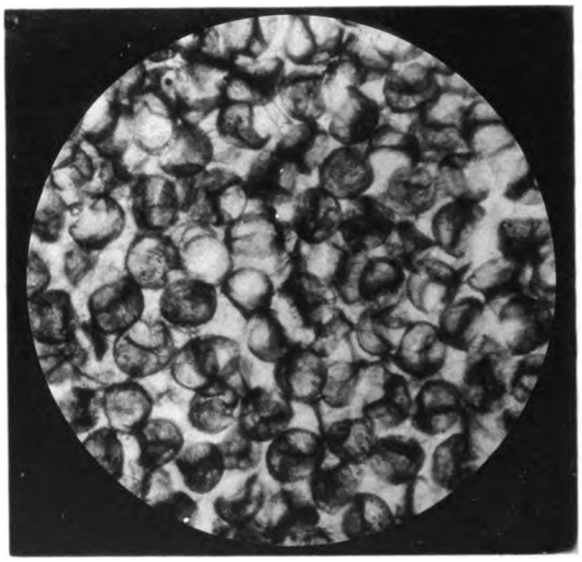

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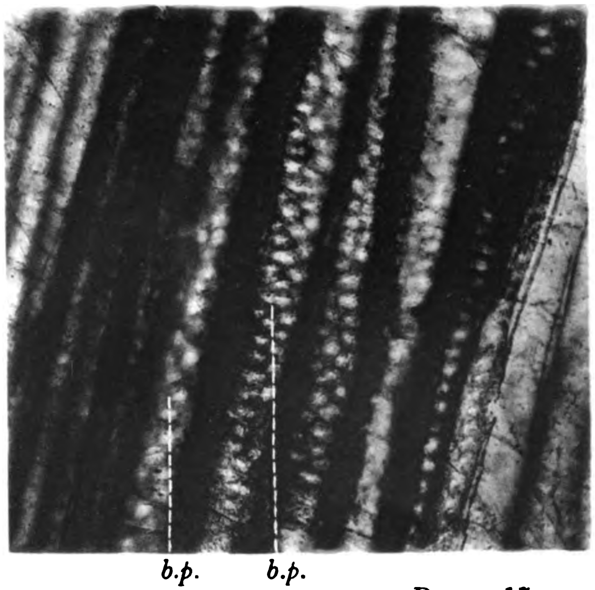

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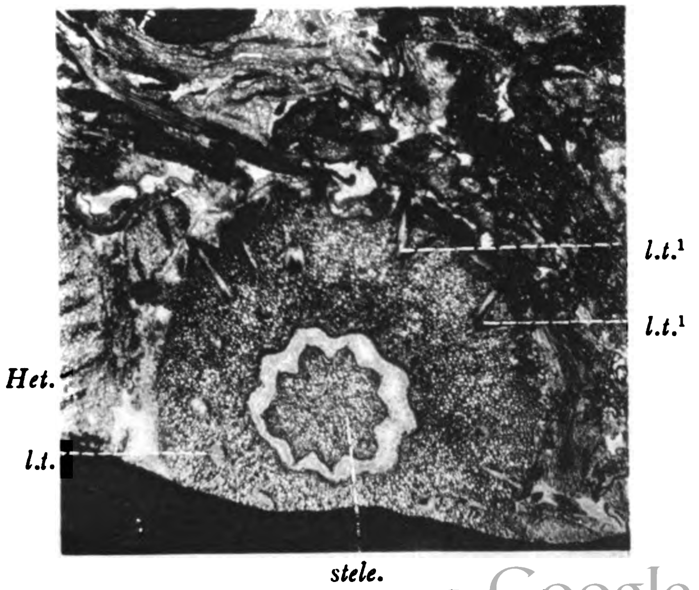

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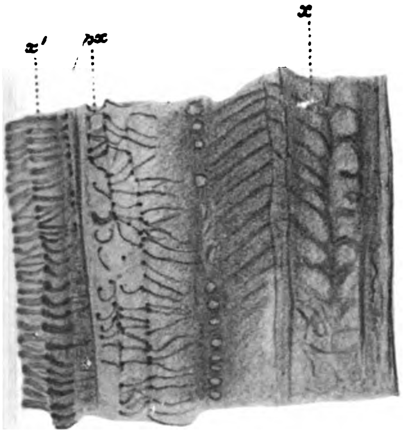

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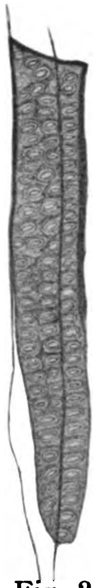
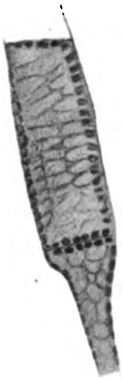


Fig. 2.



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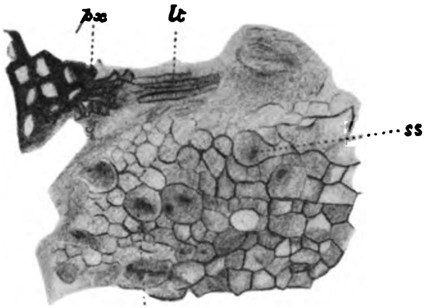

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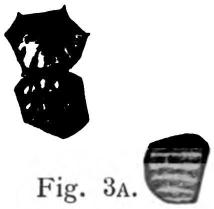
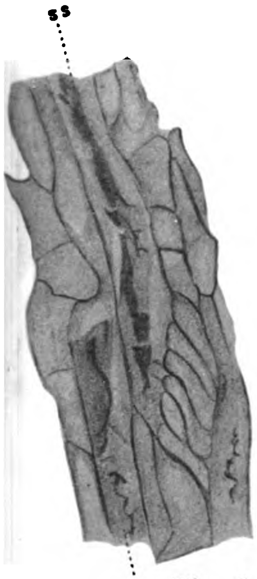


Fig. 3A.



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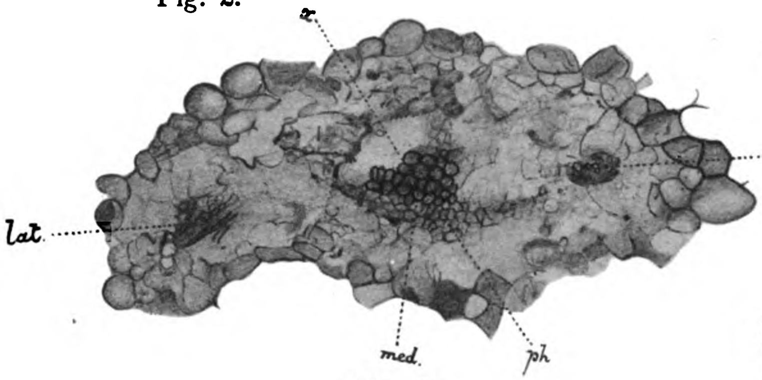
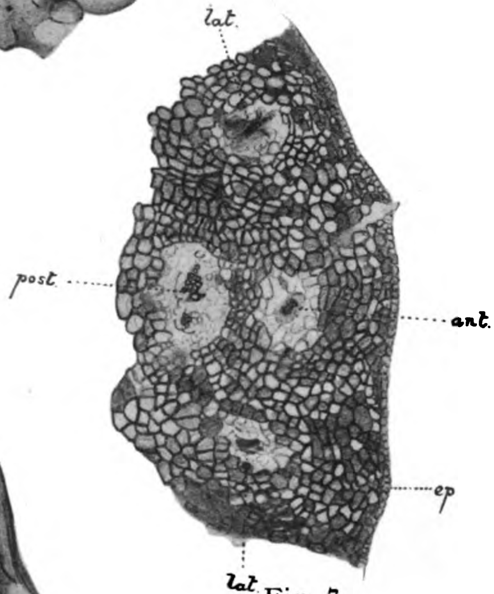


Fig. 6.



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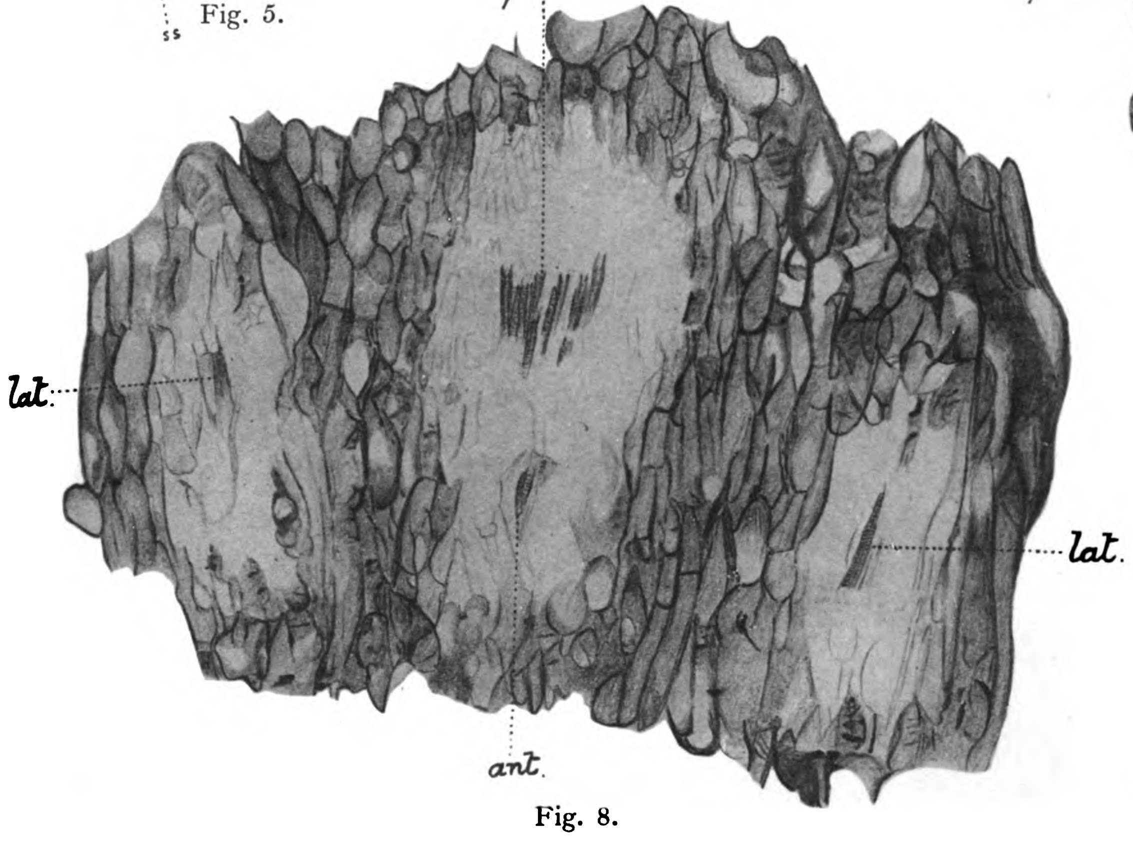

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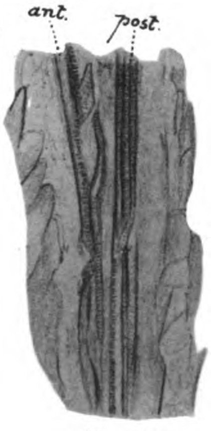

Fig. 9.

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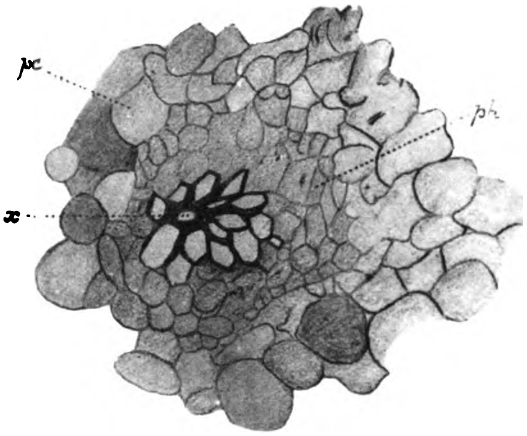
Cheirostrobus Pettycurensis.



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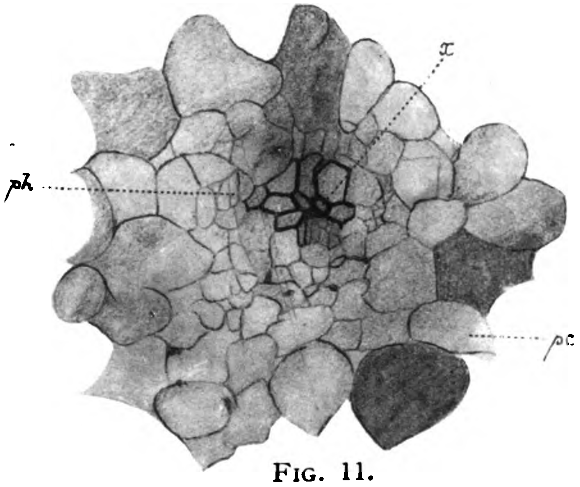

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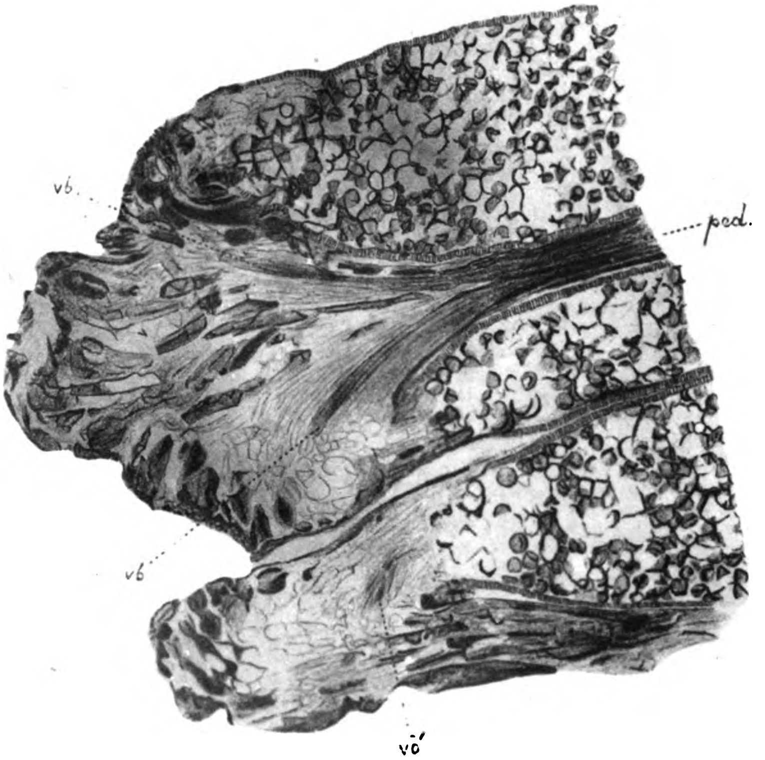

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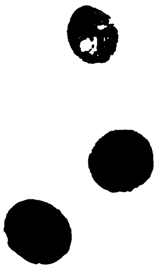

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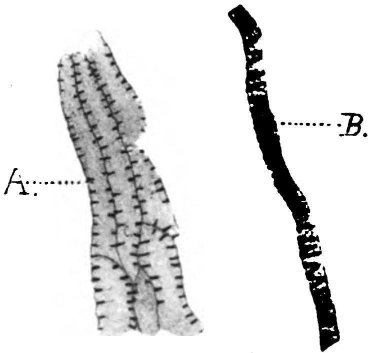

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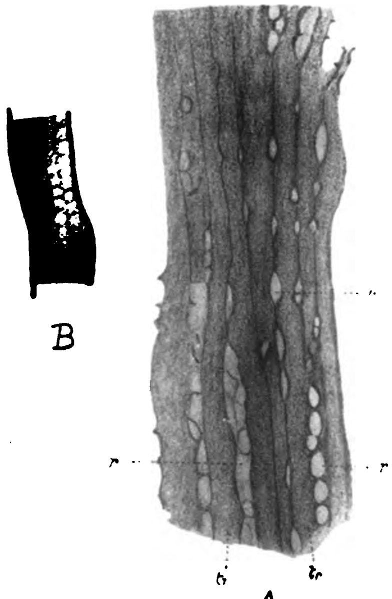

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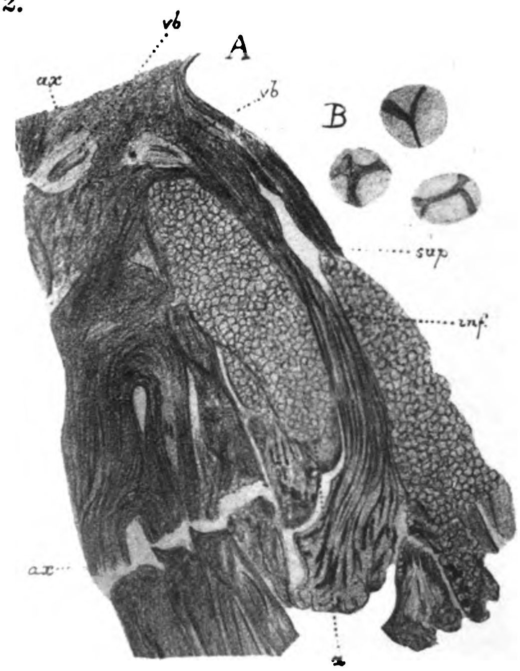

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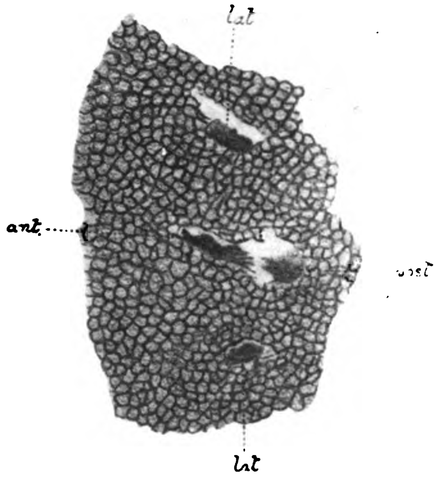
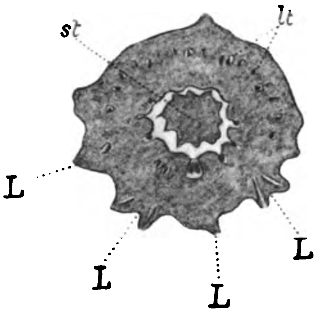


FIG. 17.

W. C. Worsdell, Del.

Cheirostrobus Pettycurensis.



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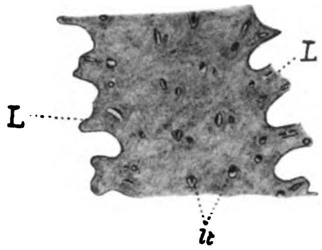
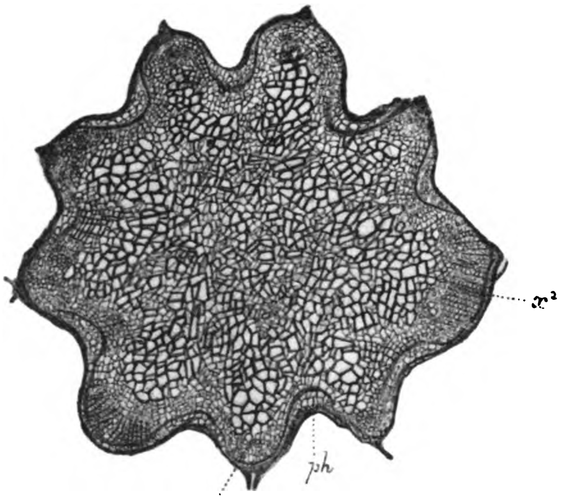


Fig. 19.



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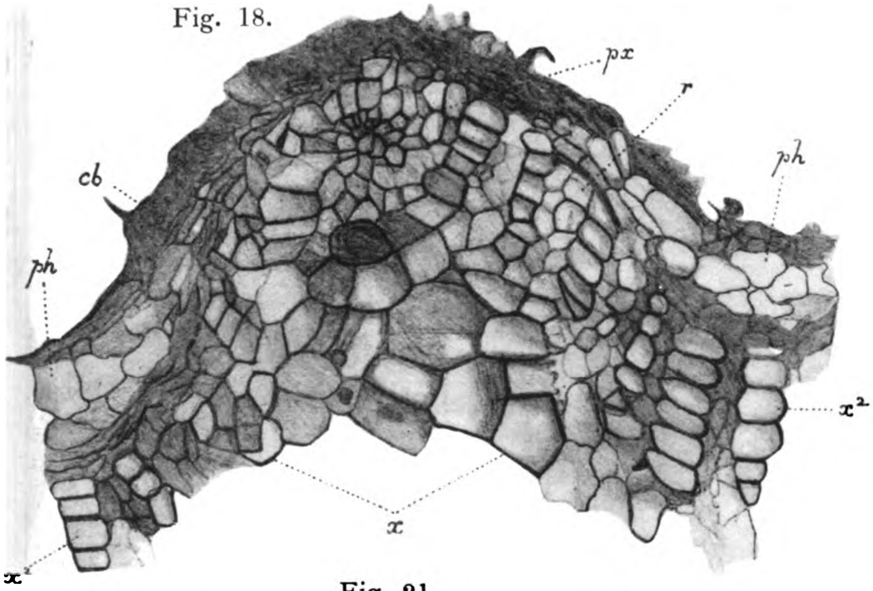

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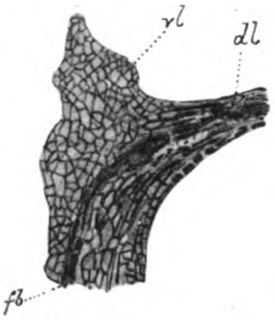

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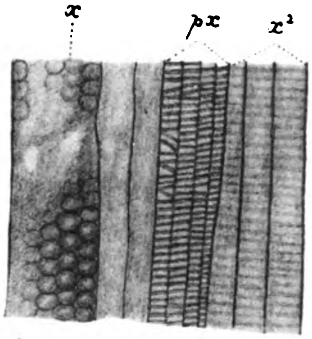

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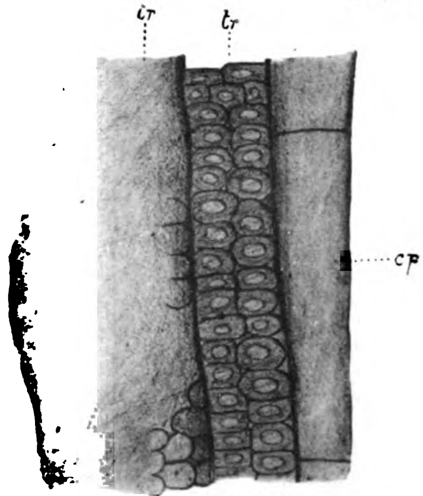

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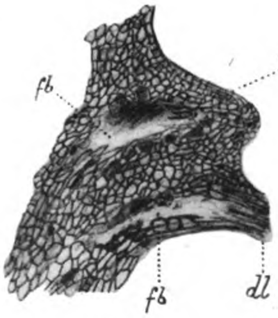

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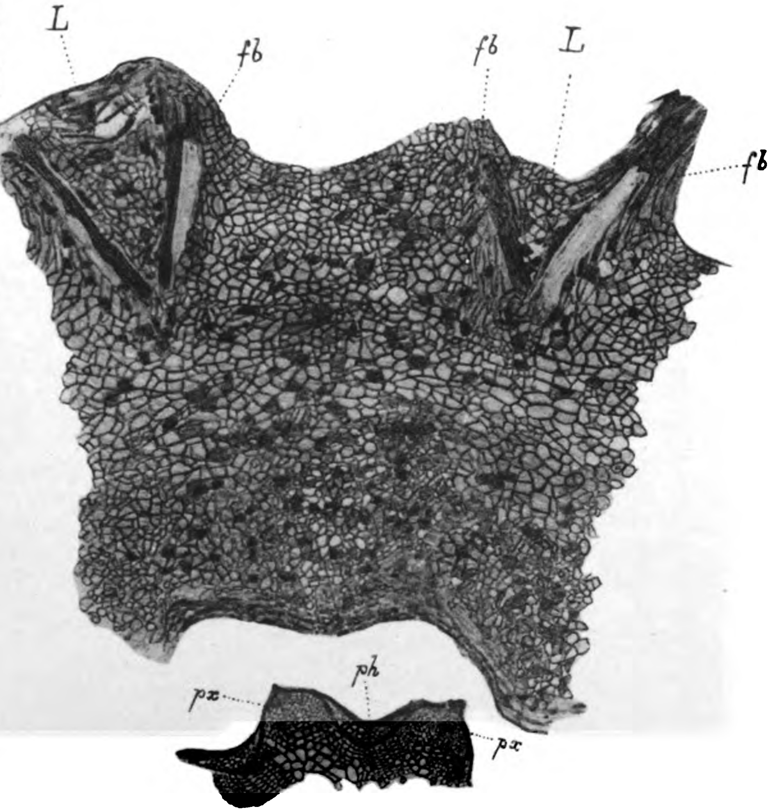

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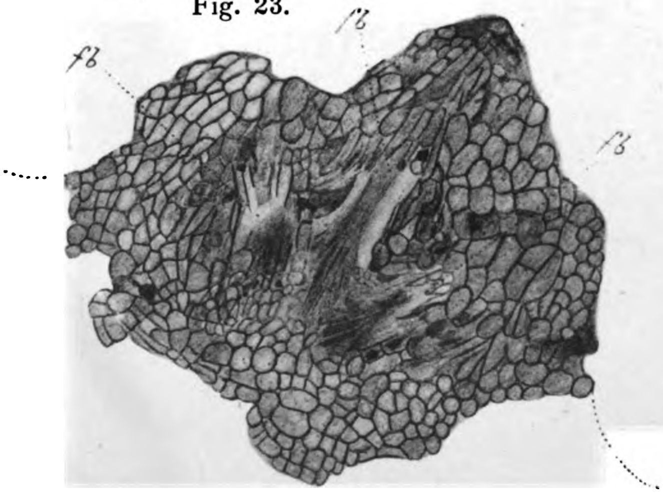


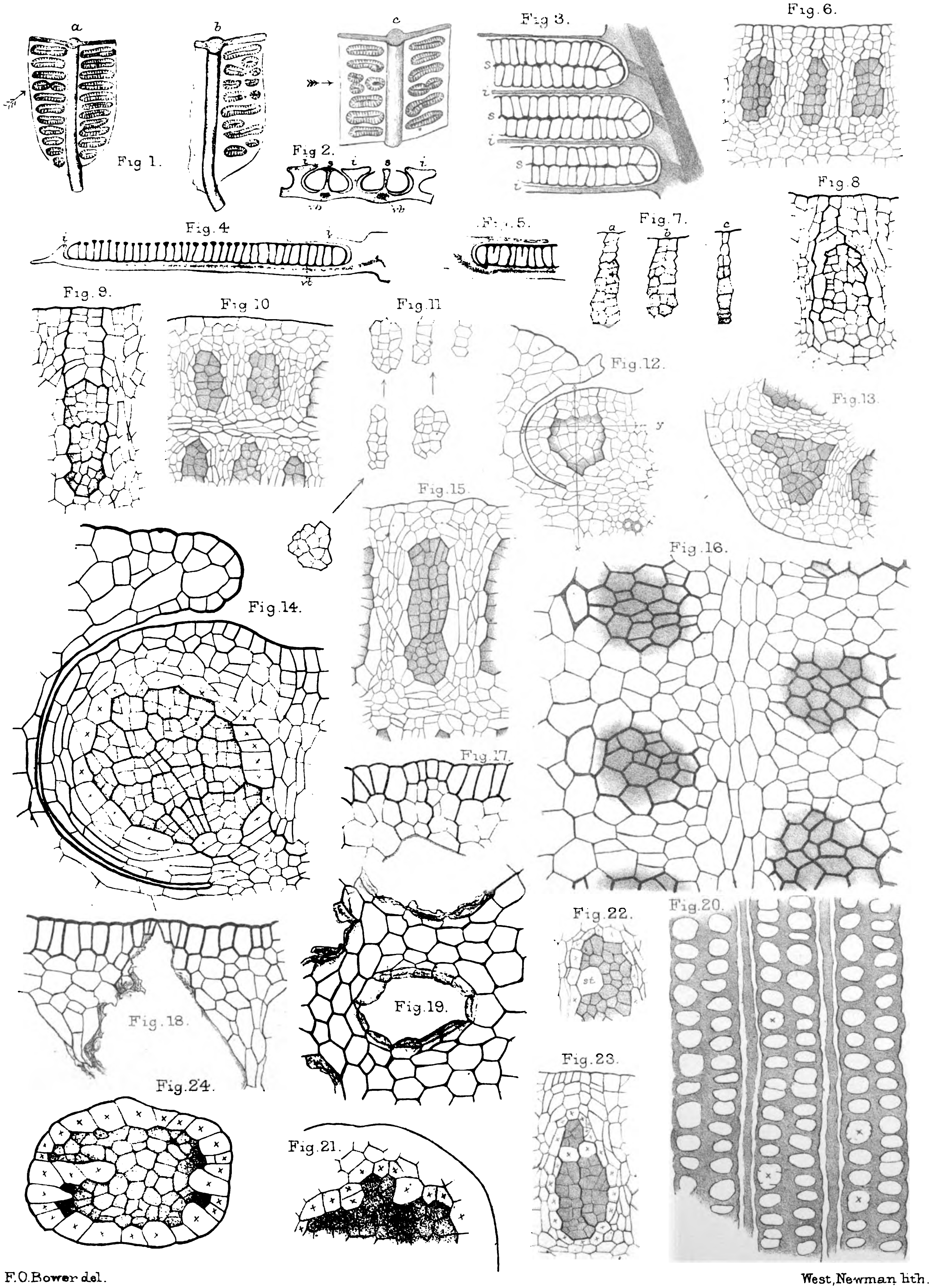
Fig. 27.

W. C. Worsdell, Del.

Cheirostrobus Pettycurensis.

Bower.

Phil. Trans. 1897. B. Plate 7.



F. O. Bower del.

West, Newman lith.

Figs. 1-24. Danæa

Fig. 25

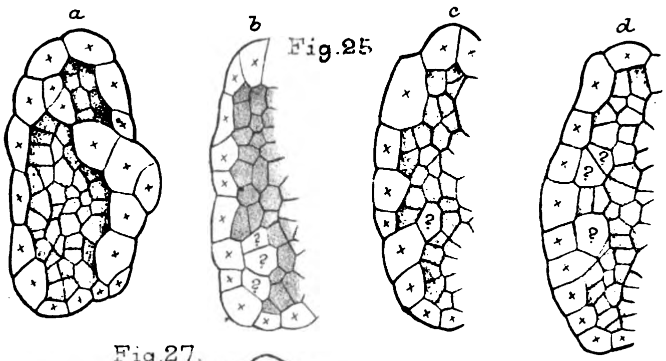
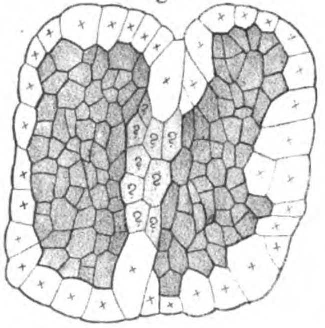


Fig. 26.



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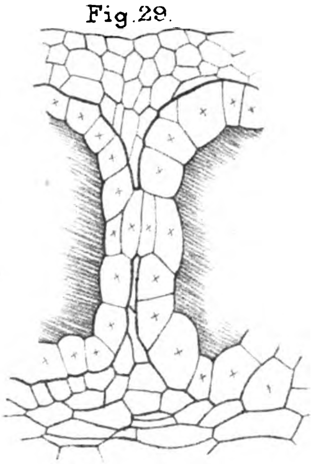

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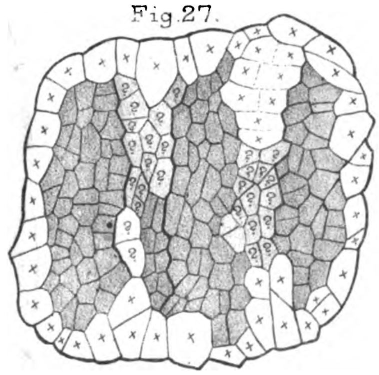

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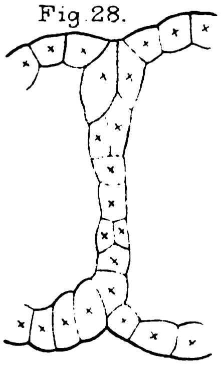

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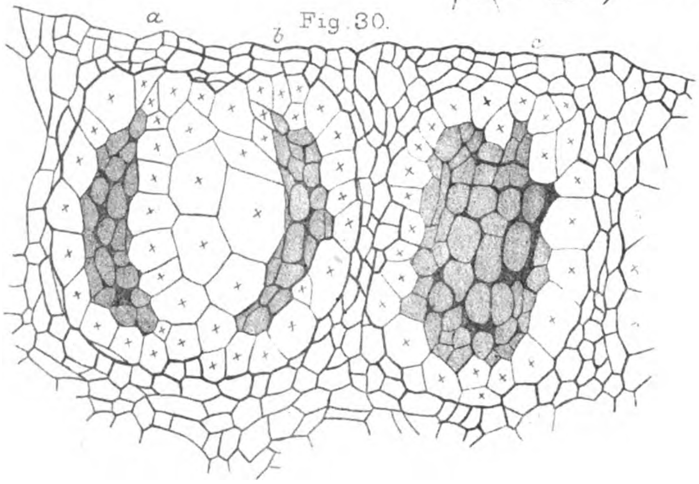

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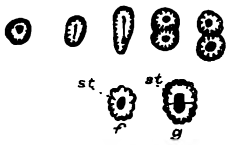

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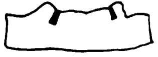
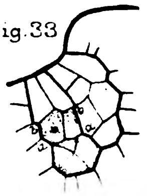


Fig. 33



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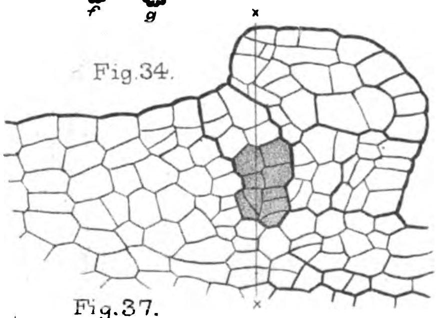

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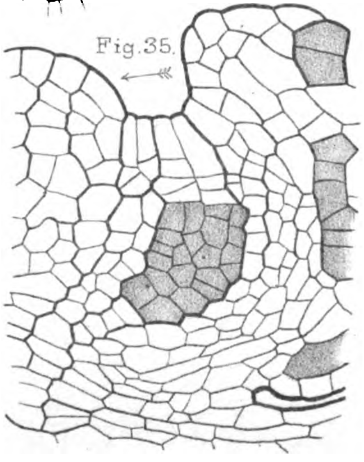

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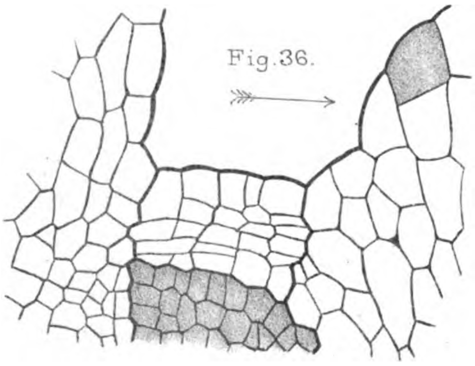

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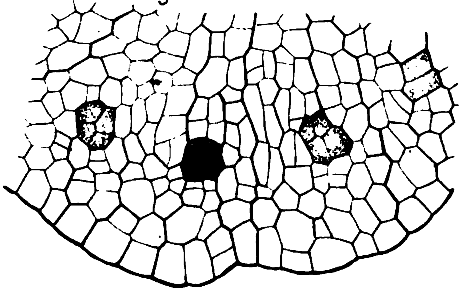

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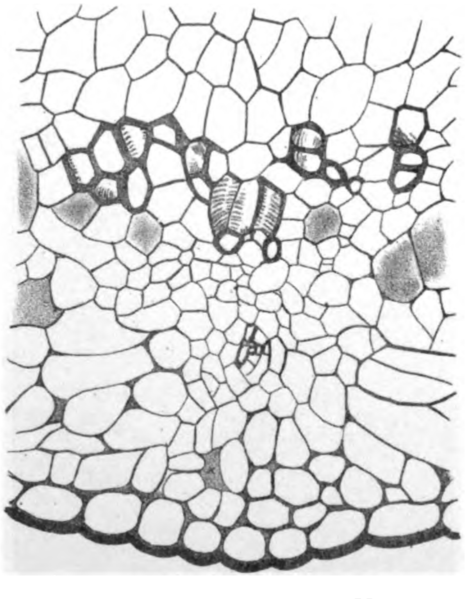

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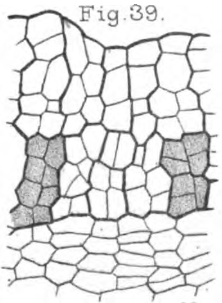

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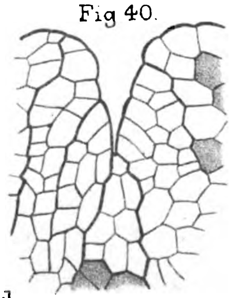

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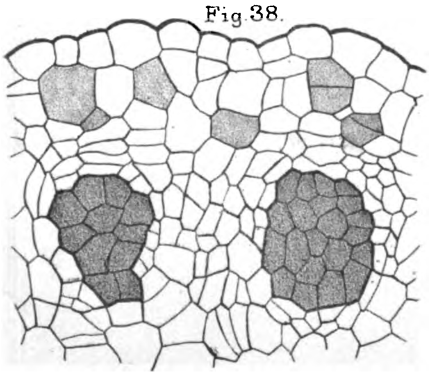
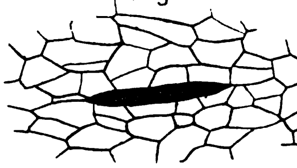


Fig. 41

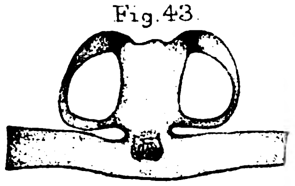


F O. Bower del.

West, Newman lith.

Figs. 25-30. Danæa elliptica, *Sm.*
Figs. 31-42. Kaultussia æsculifolia, *Blume.*

Fig. 43.



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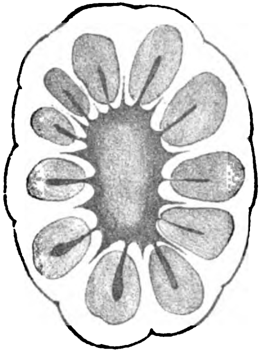

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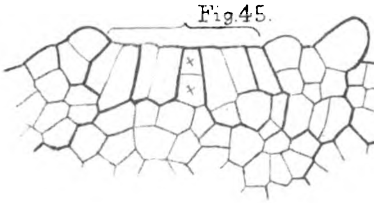

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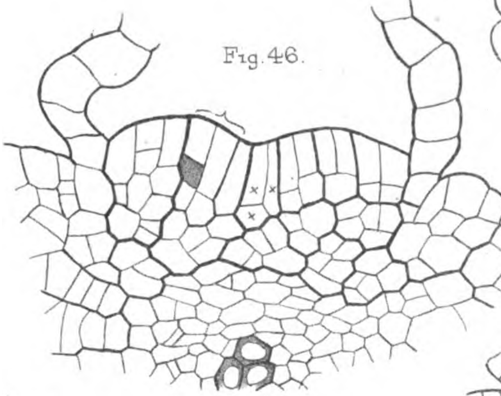

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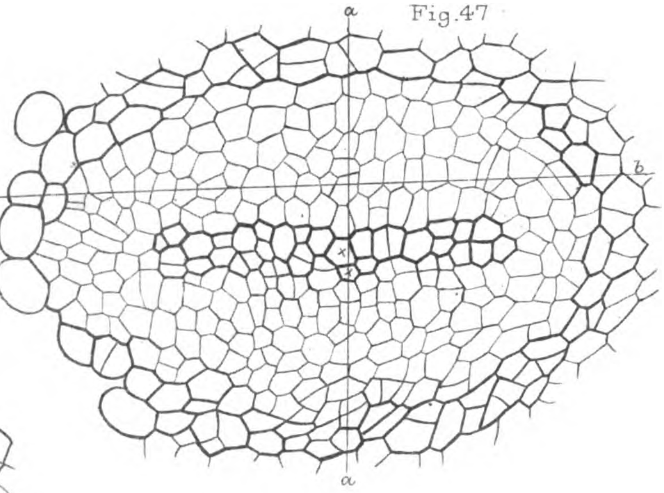

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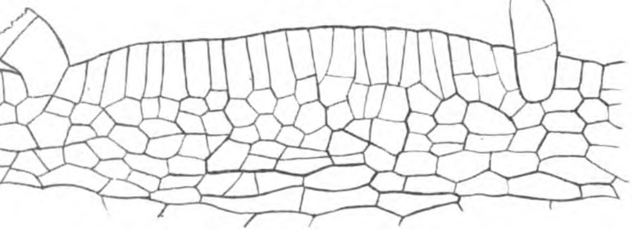

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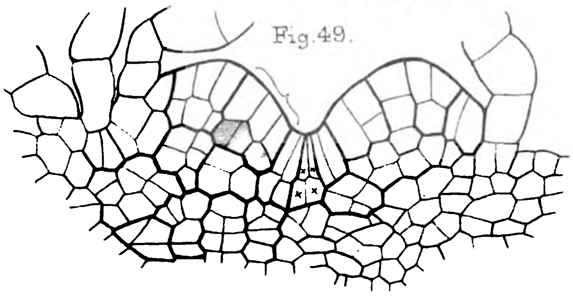

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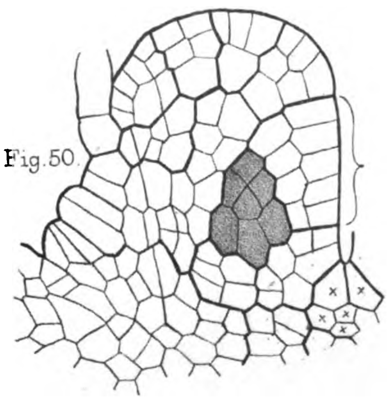

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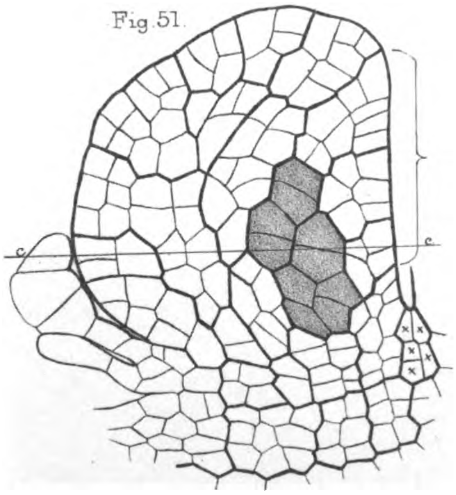

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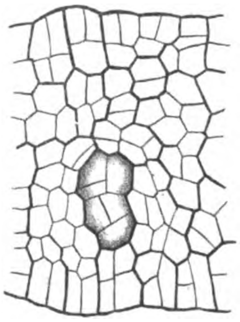

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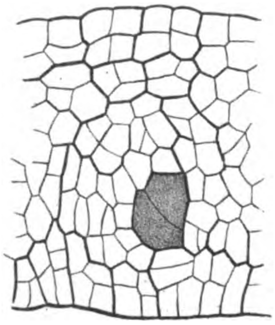

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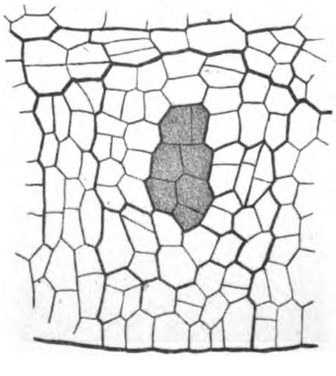

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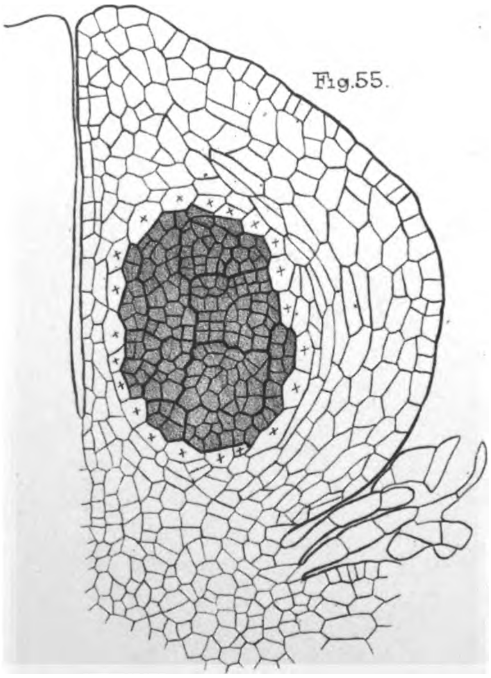

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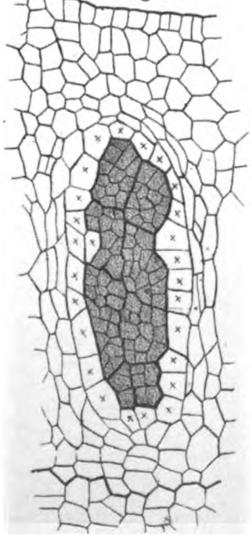

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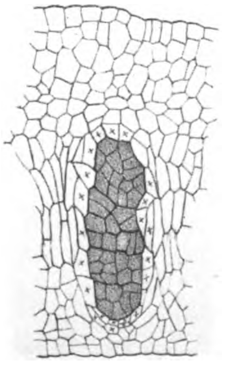
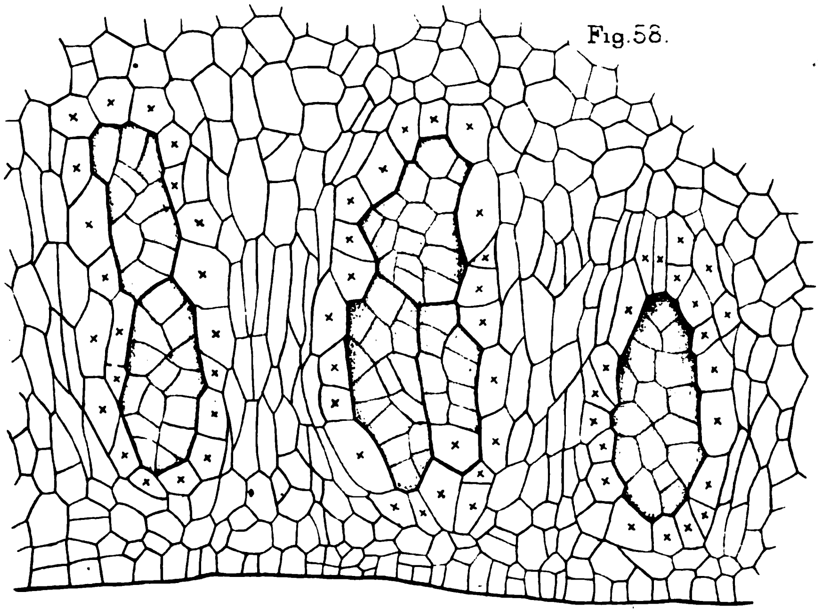


F. O. Bower del.

Figs. 43-44. Kaulfussia æsculifolia. *Blume.*
Figs. 45-57. Marattia fraxinea. *Smith.*

West, Newman lith.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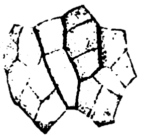
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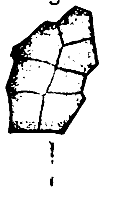
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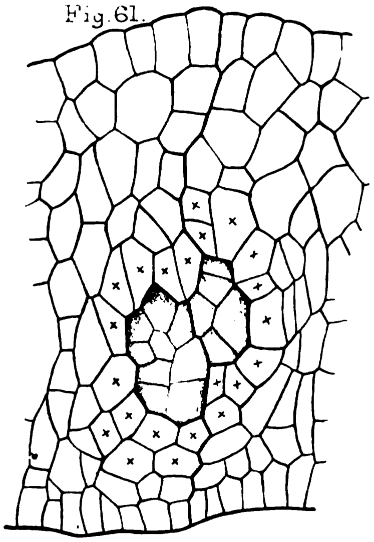
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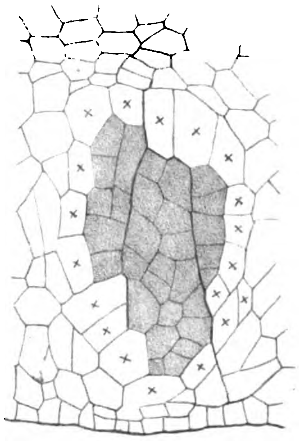
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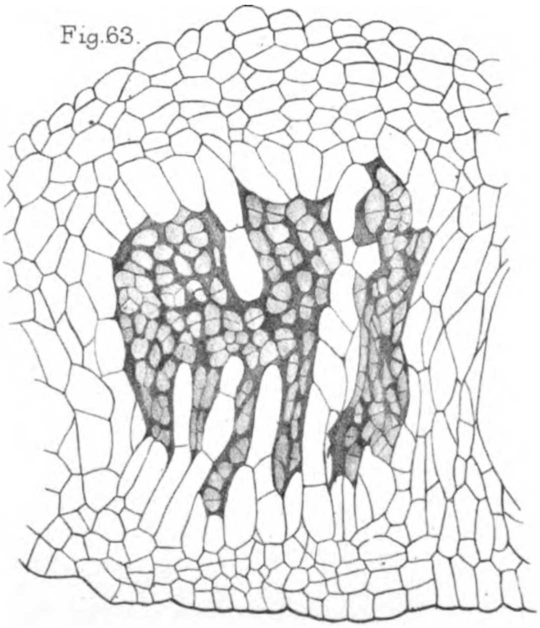
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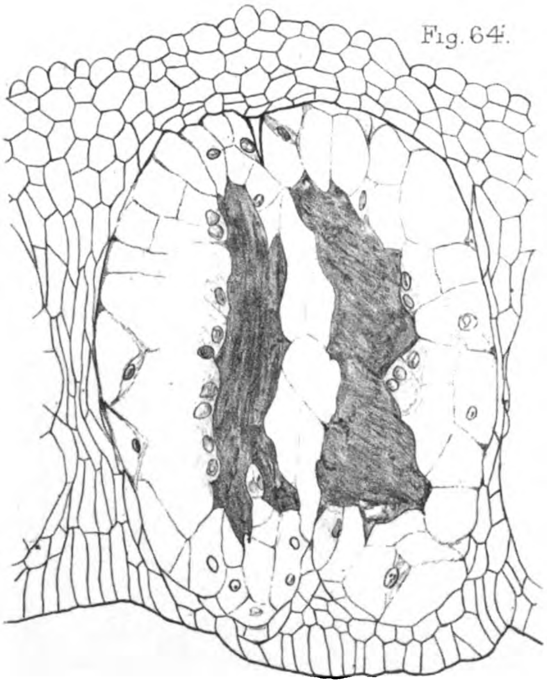
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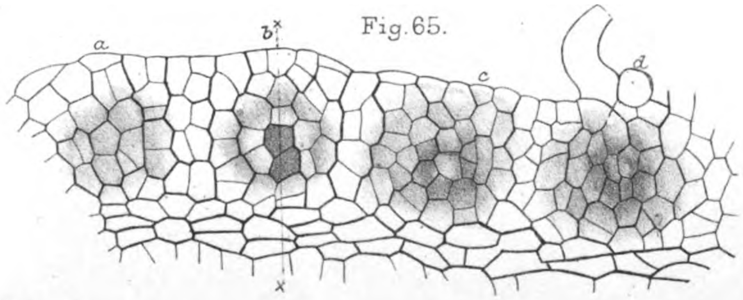
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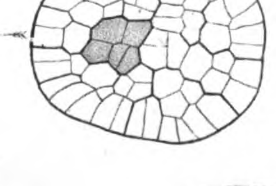
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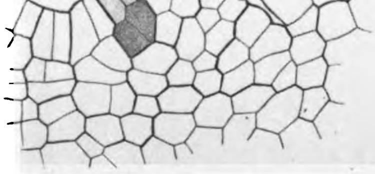
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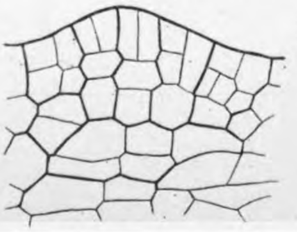
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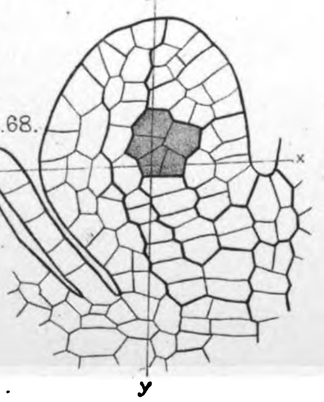
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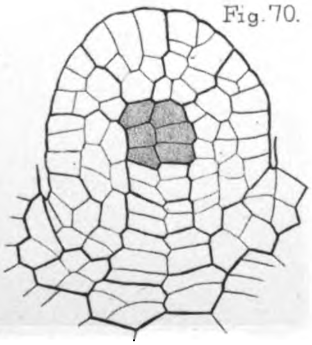


Fig. 70.

F. O. Bower del. West, Newman lith.

Figs. 58-64. Marattia fraxinea. *Smith.*
Figs. 65-70. Angiopteris evecta. *Hoffm.*

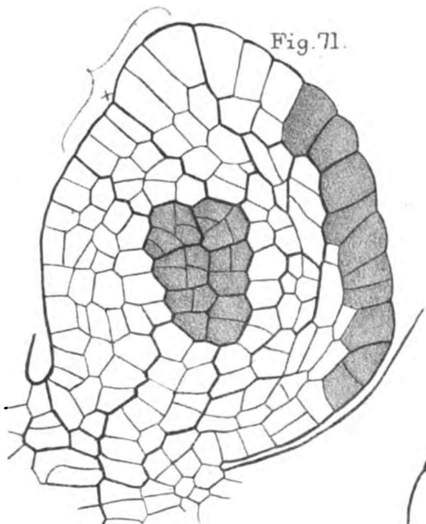
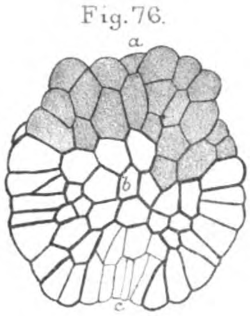


Fig. 71.



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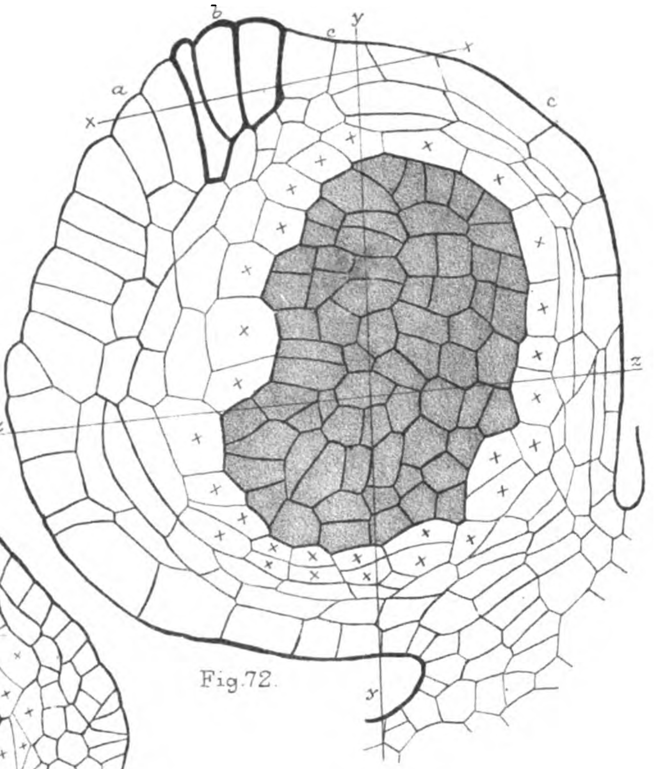

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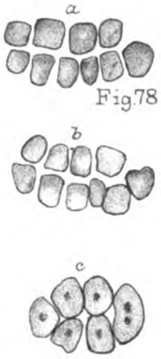

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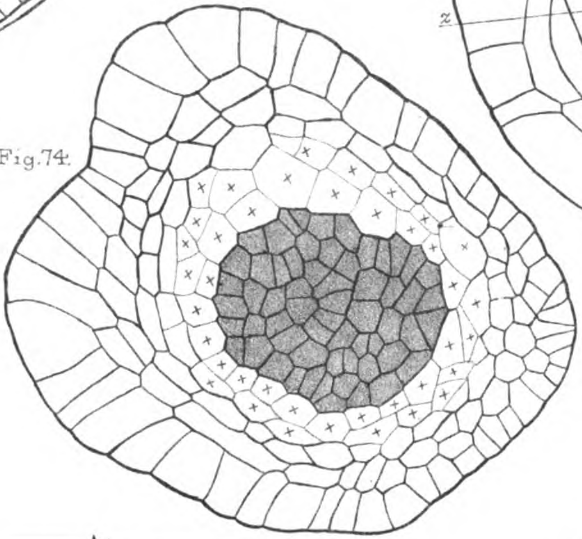

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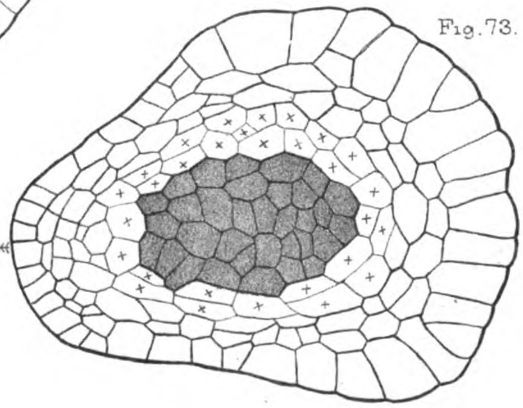

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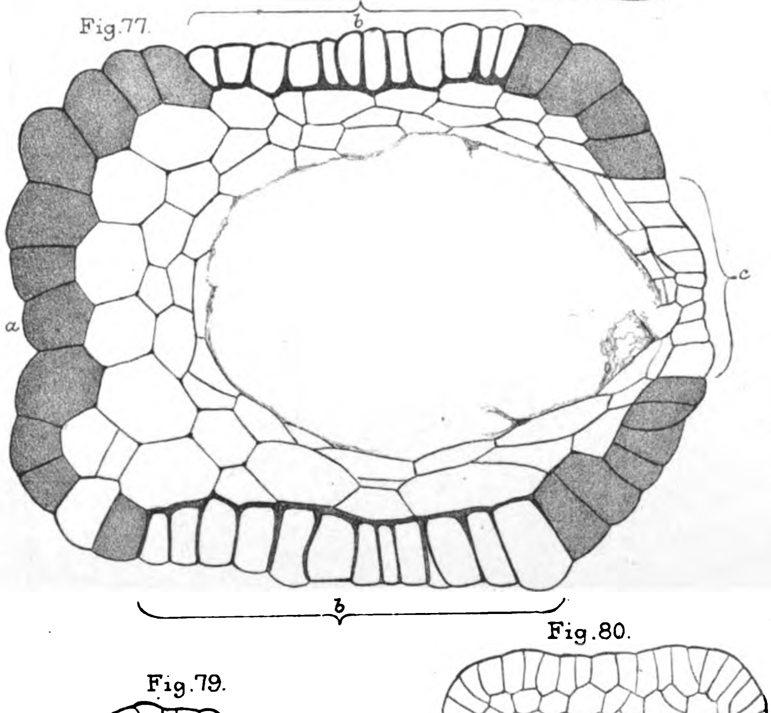

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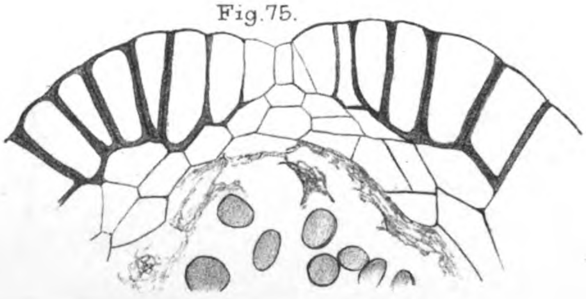

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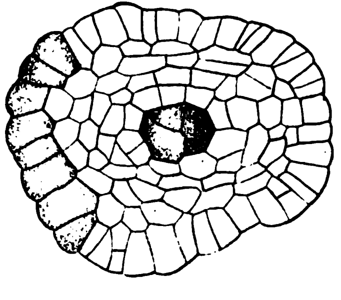

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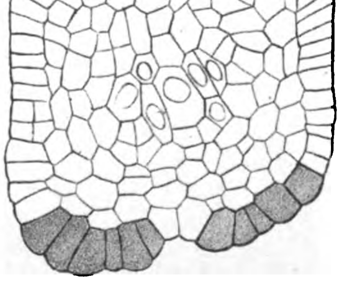

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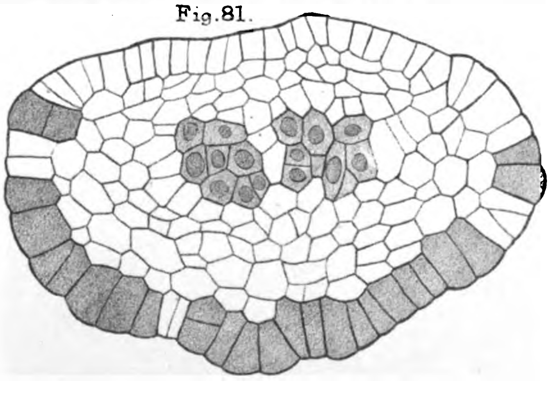
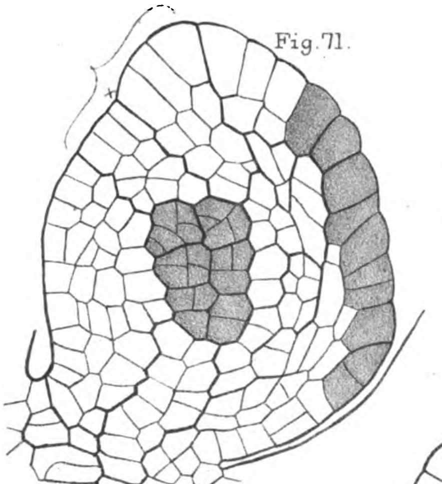


Fig. 81.

F.O. Bower del.

West Newman lith.

Figs. 71-81. Angiopteris evecta. *Hoffm.*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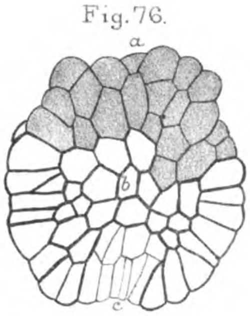
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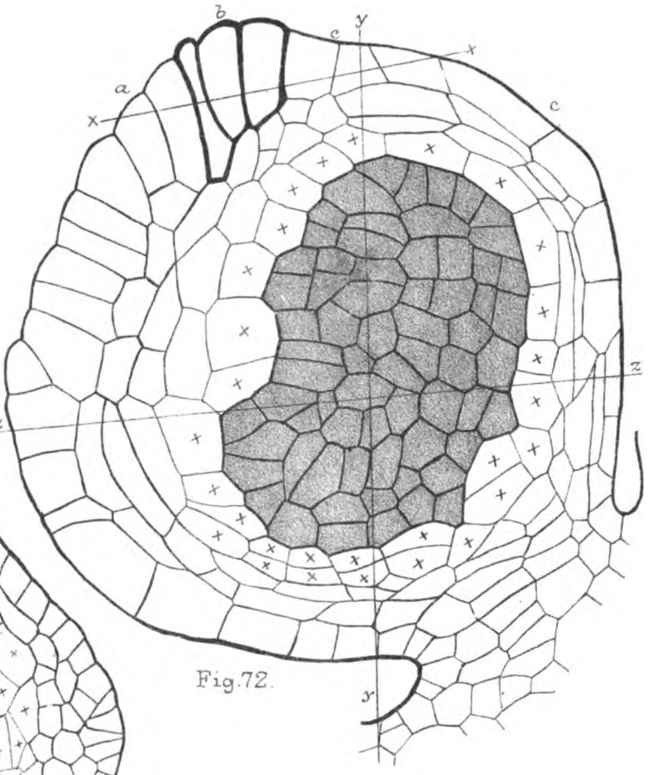
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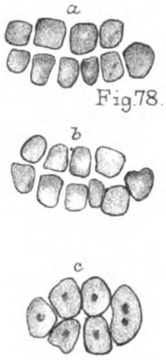
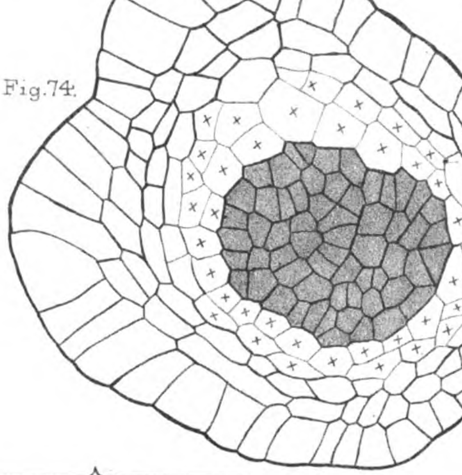


Fig. 78.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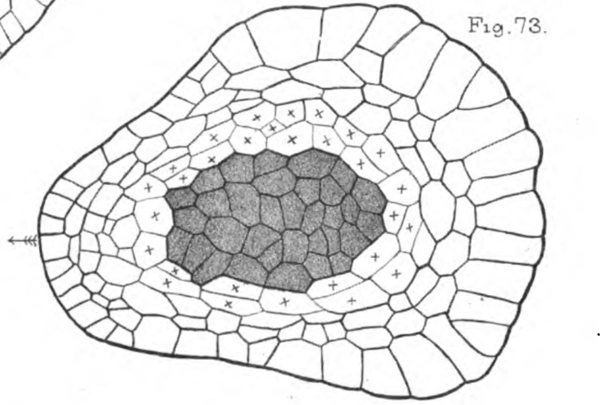
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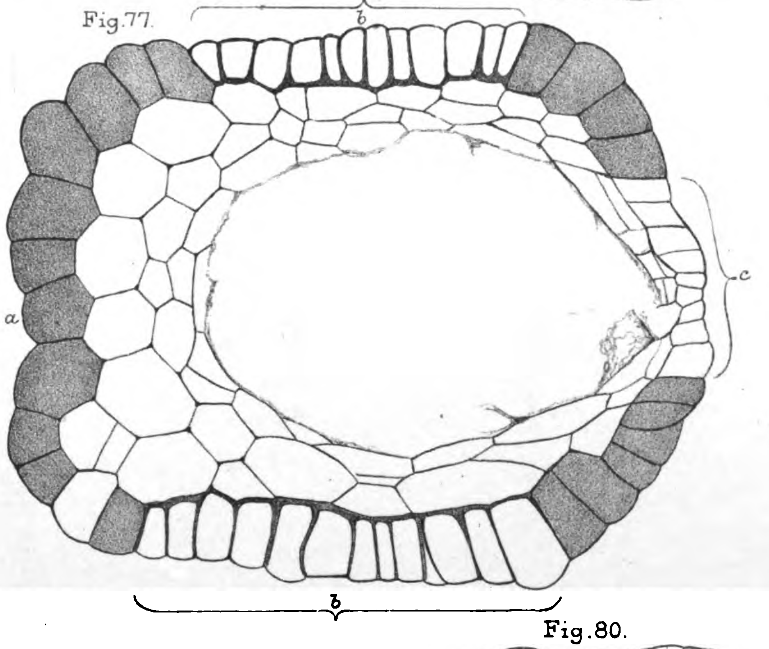
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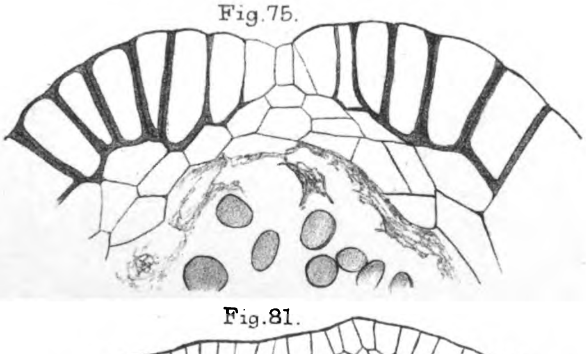
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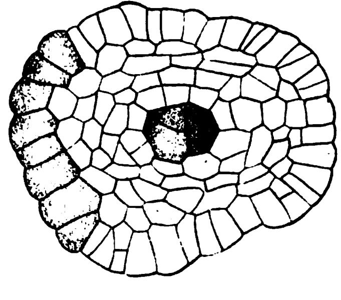
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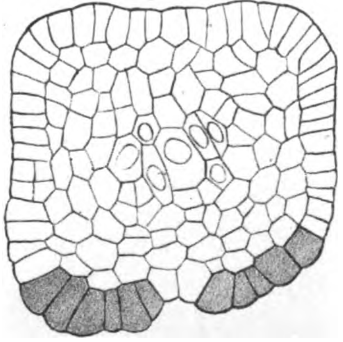
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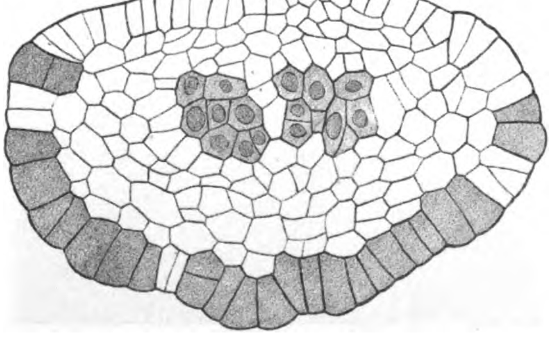


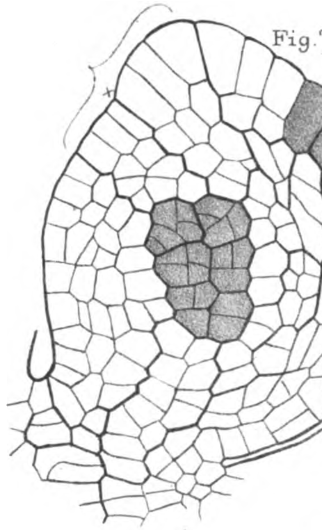
Fig. 81.

F. O. Bower del.

West Newman lith.

Figs. 71-81. Angiopteris evecta. Hoffm.

Fig. 71.



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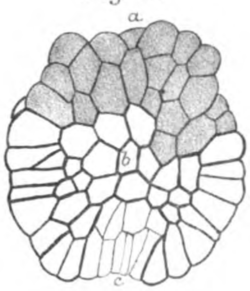

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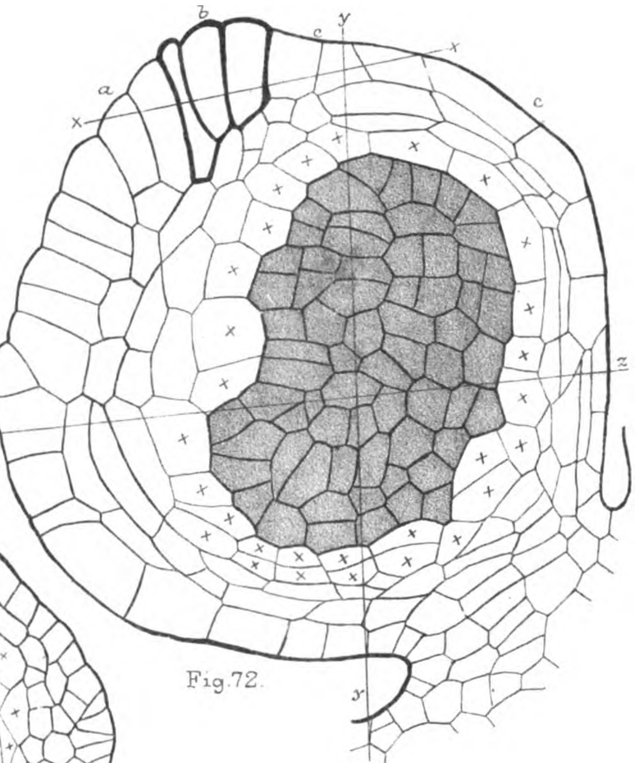

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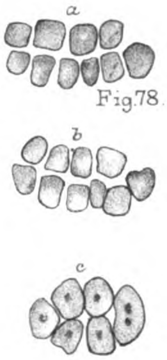

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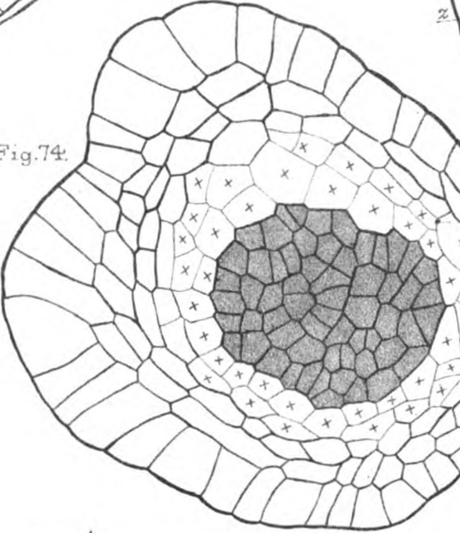

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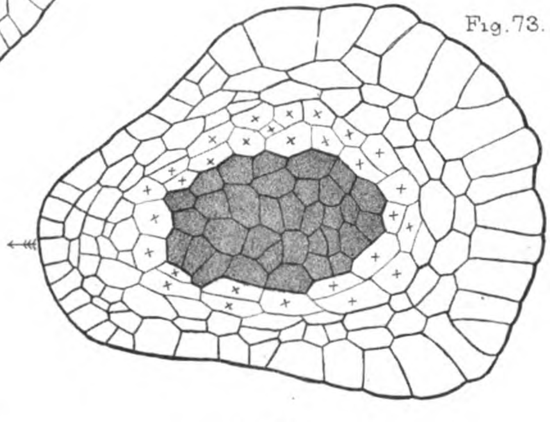

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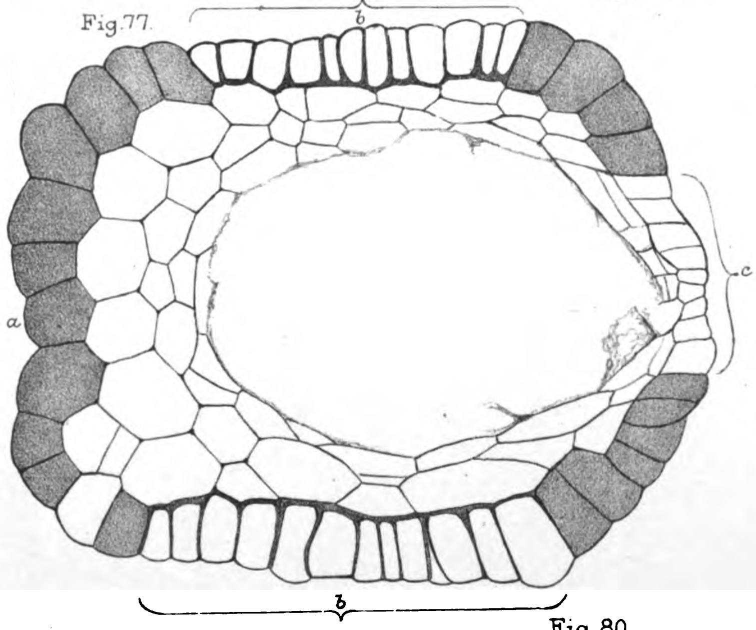

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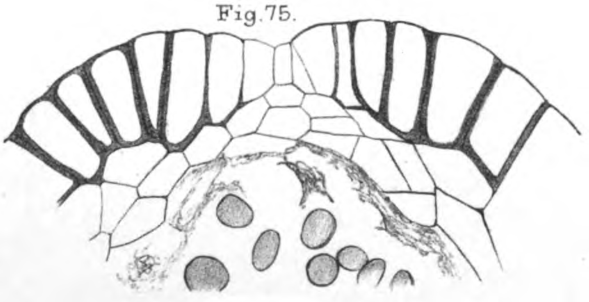

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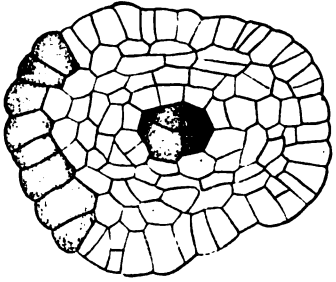

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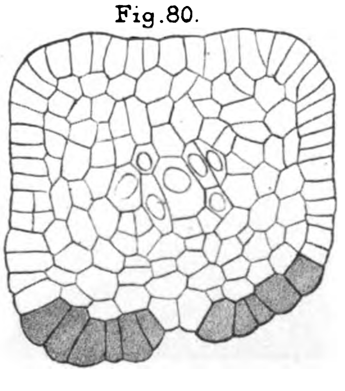

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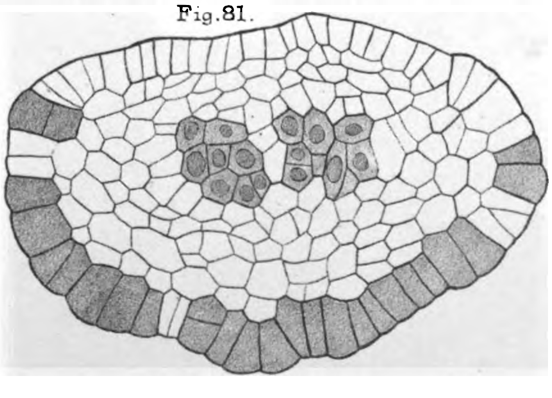


F. O. Bower del. West Newman lith.

Figs. 71-81. Angiopteris evecta *Hoffm.*

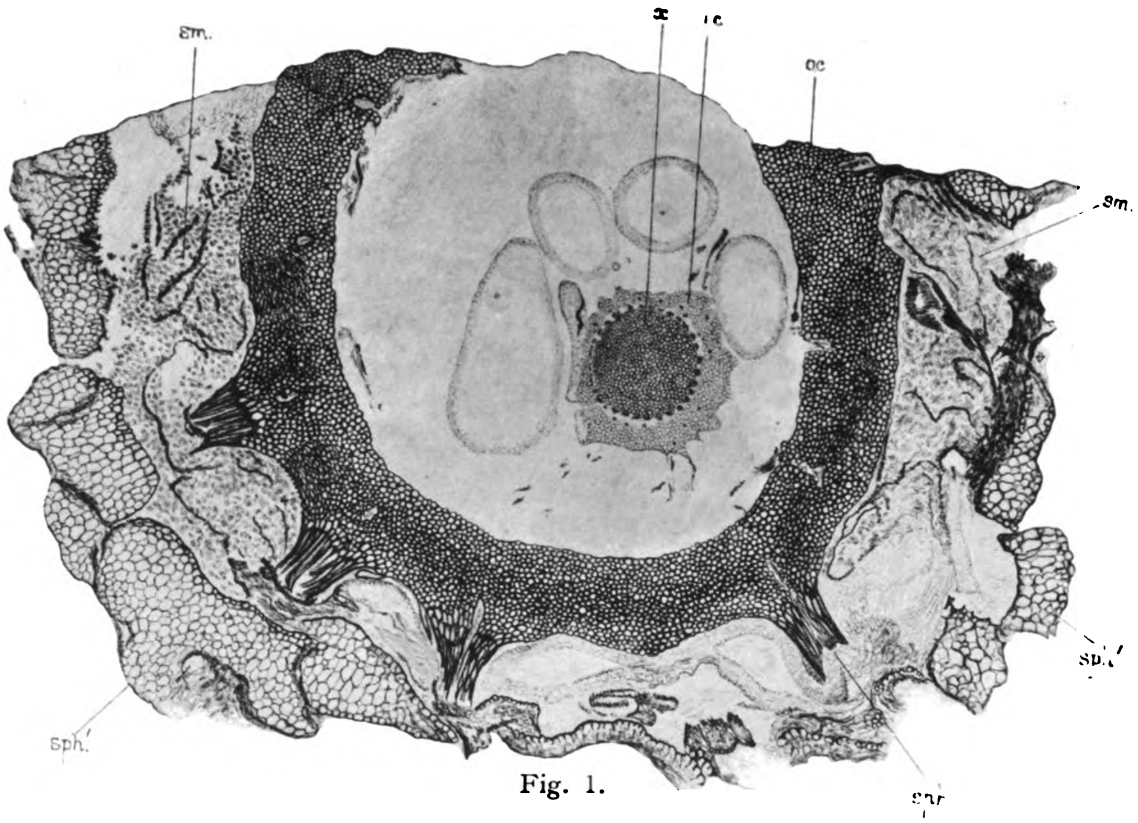


Fig. 1.

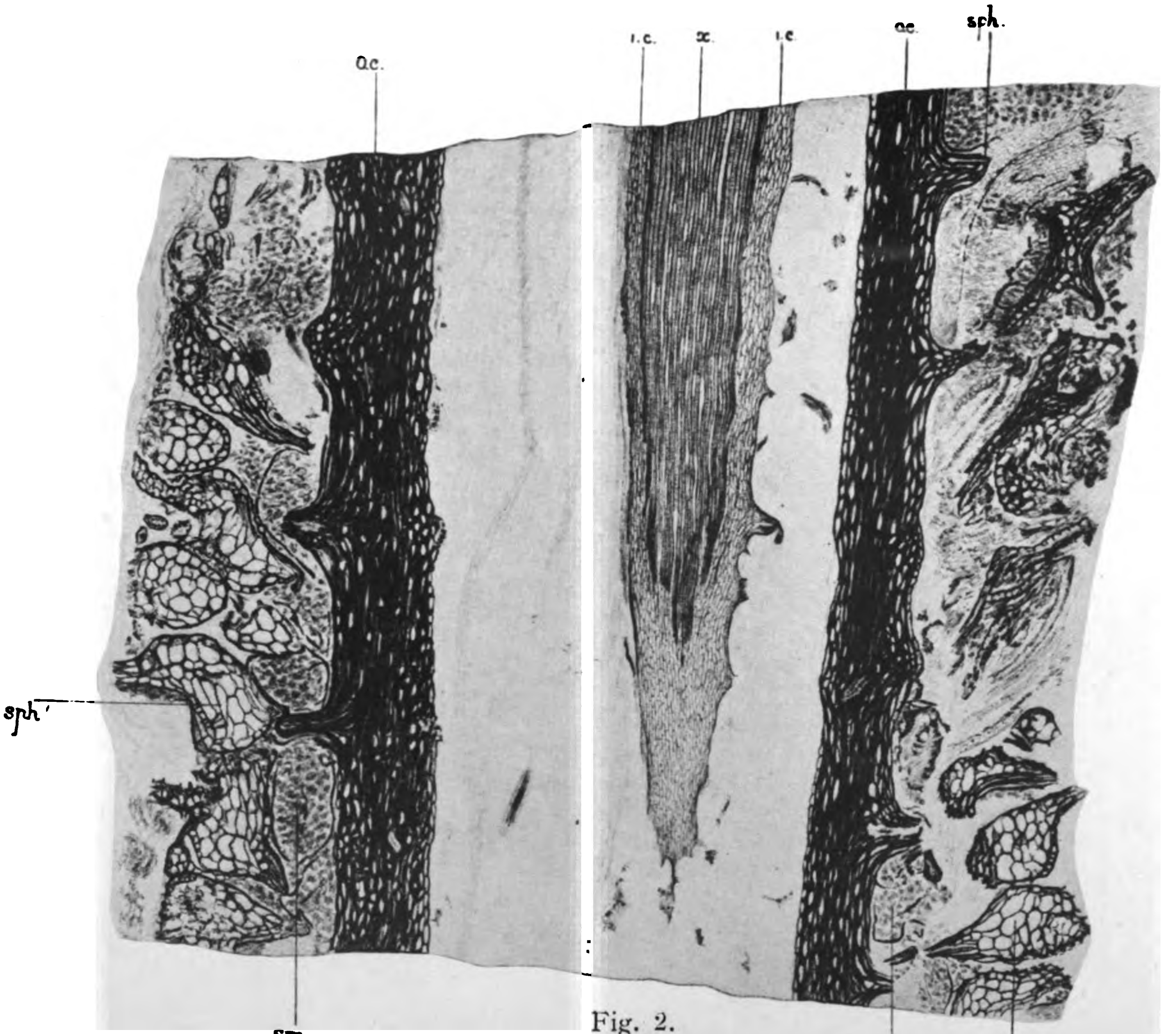
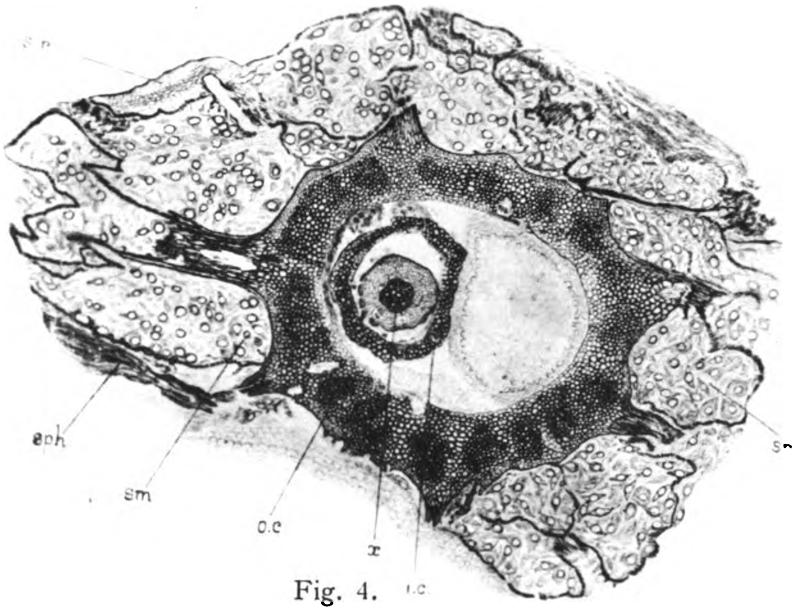


Fig. 2.

G. T. Gwilliam, del.

Spencerites majusculus.



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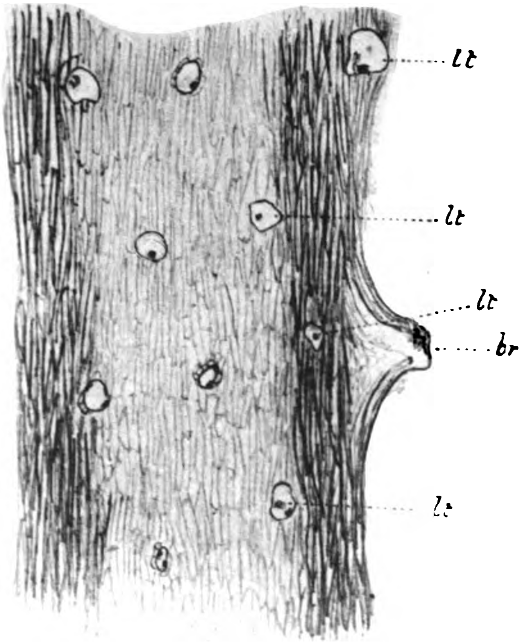

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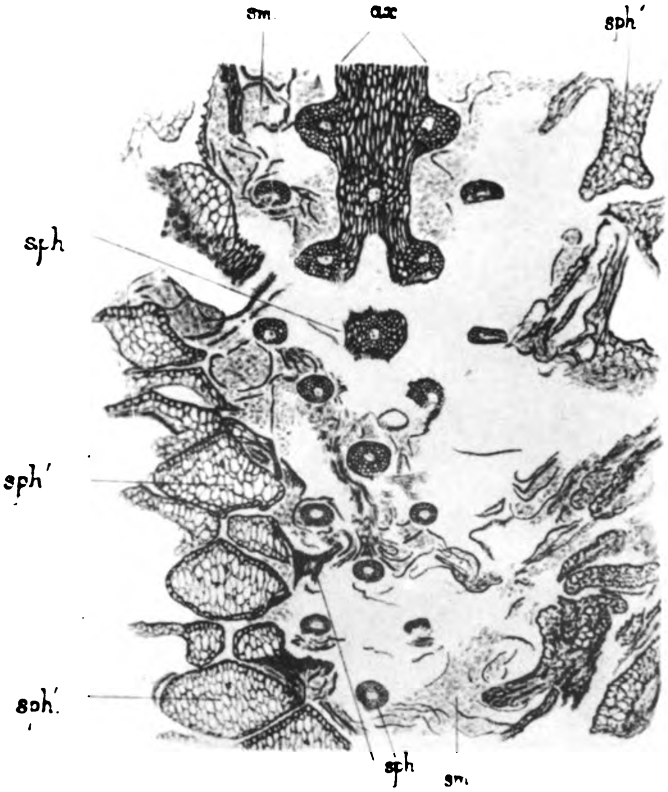

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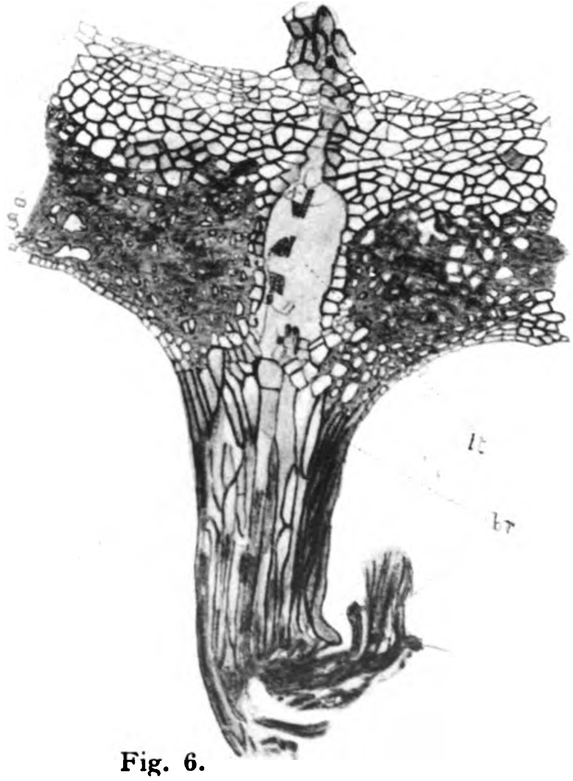

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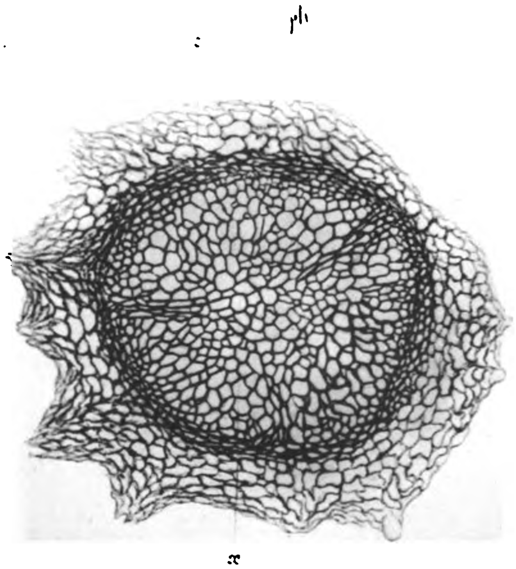

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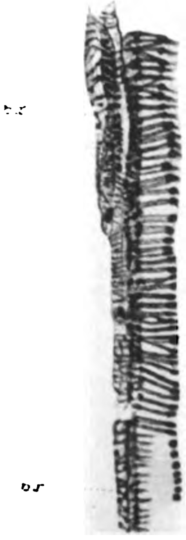


Fig. 8A.

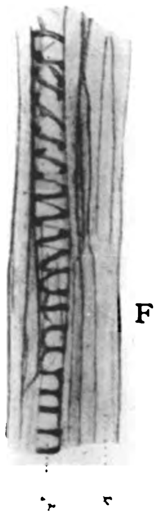
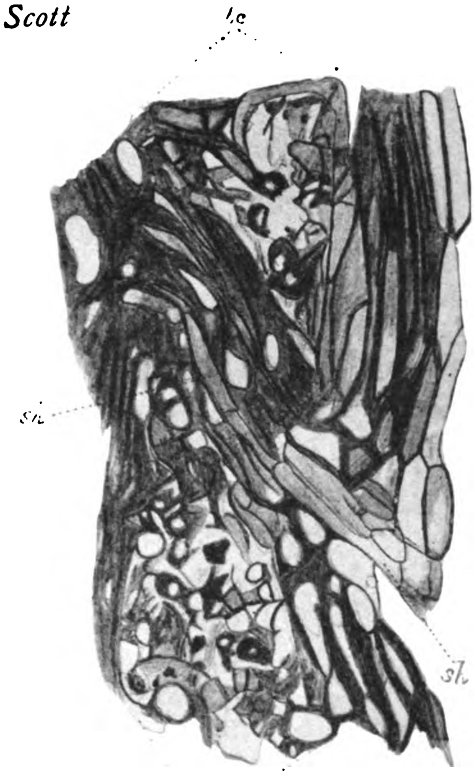


Fig. 8B.

G. T. Gwilliam and W. C. Worsdell, del.

Fig. 3. Spencerites majusculus. Figs. 4—8B. S. insignis.



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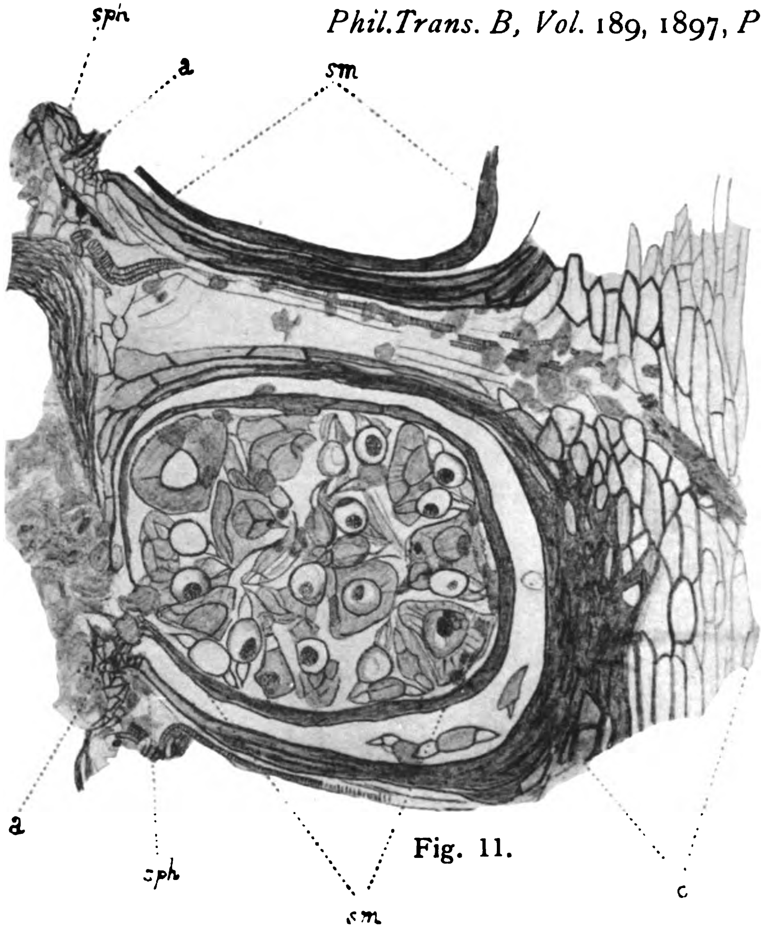

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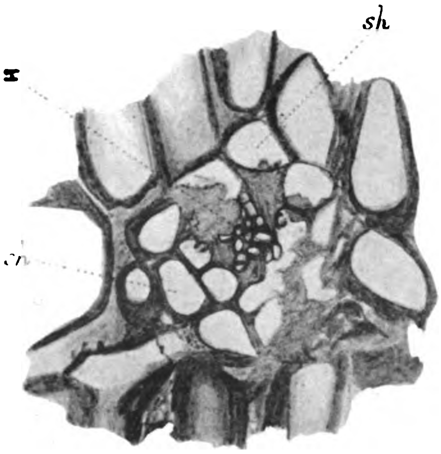

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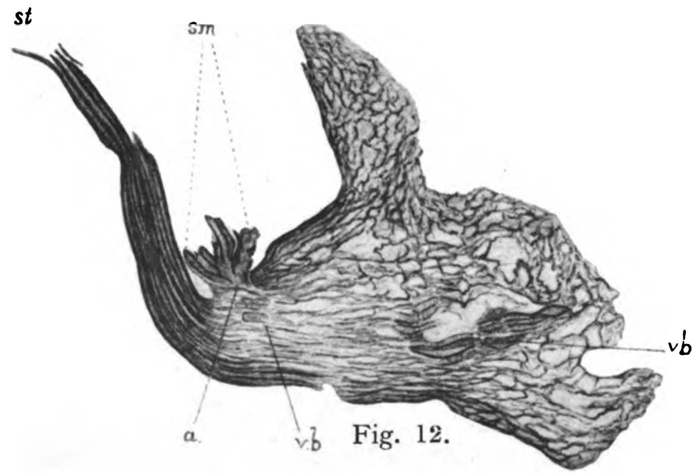

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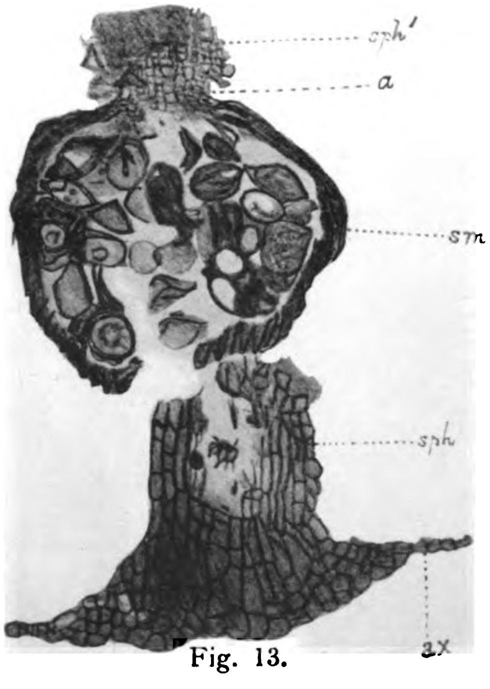

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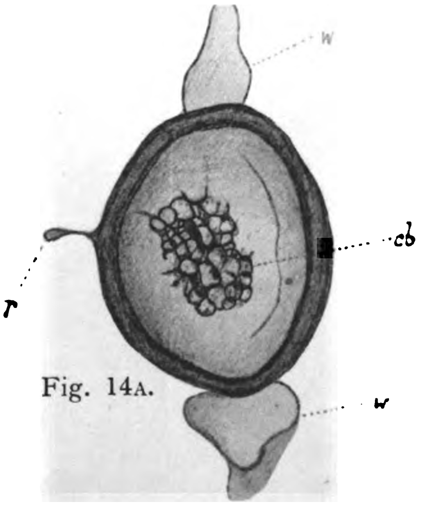

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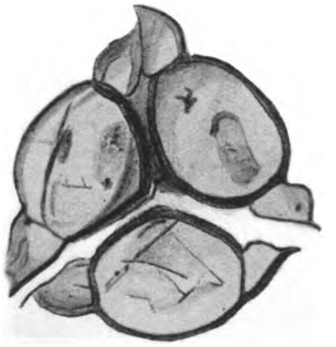
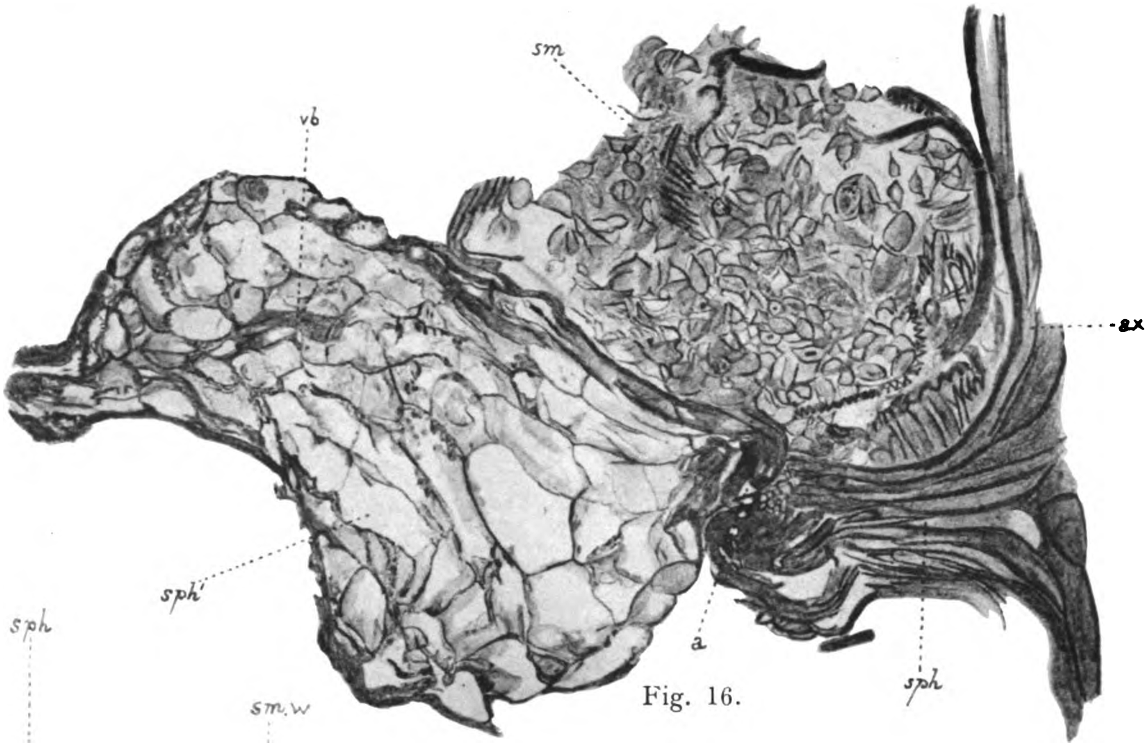


Fig. 14B.

W. C. Worsdell and G. T. Gwilliam, del.

Spencerites insignis.



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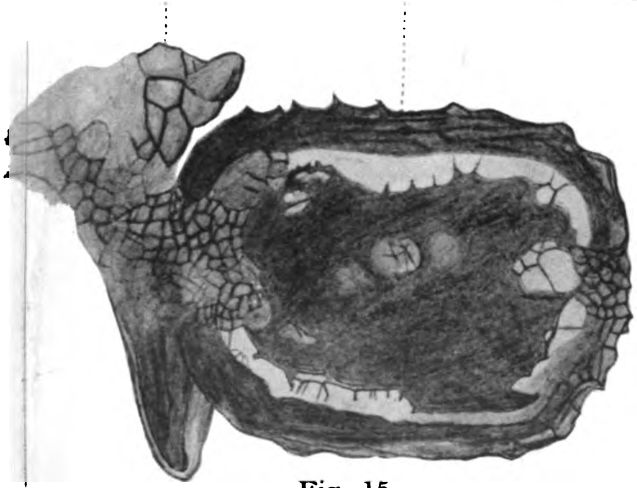

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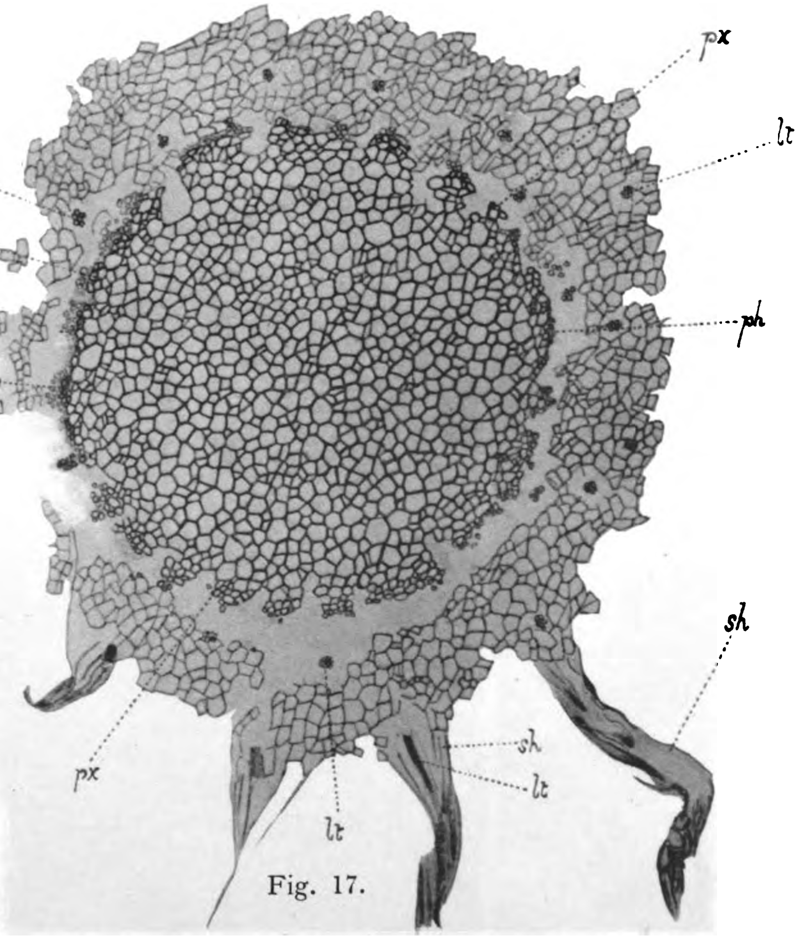

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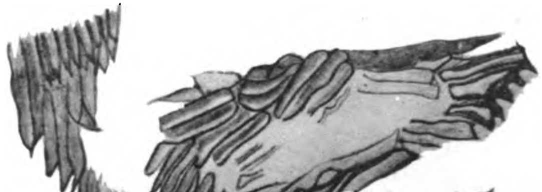

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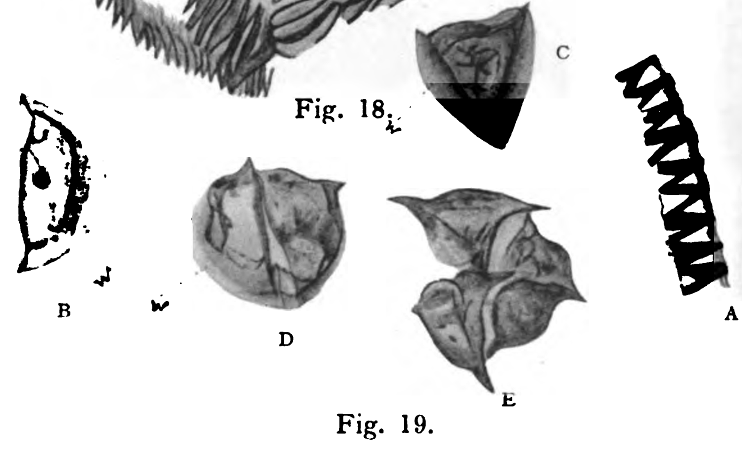


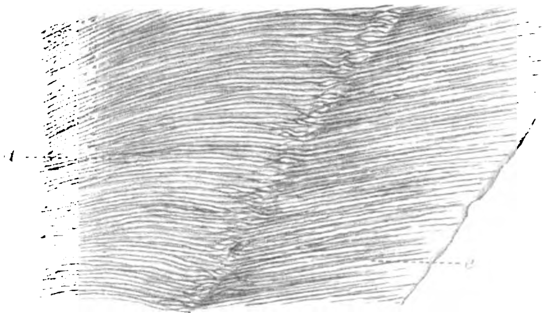
Fig. 19.

Fig. 15. Spencerites insignis.

Fig. 16—19. S. majusculus.

W. C. Worsdell, del.

Fig. 1. x 80



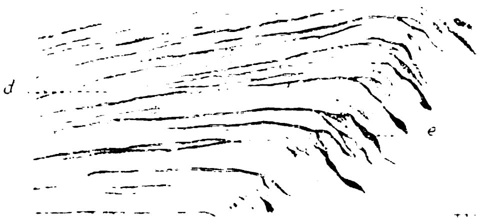


Fig. 2. x 200

Fig. 4.

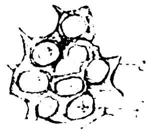


Fig. 3. x 1000

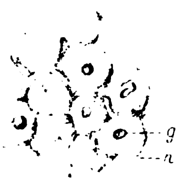


Fig. 5. x [illegible]

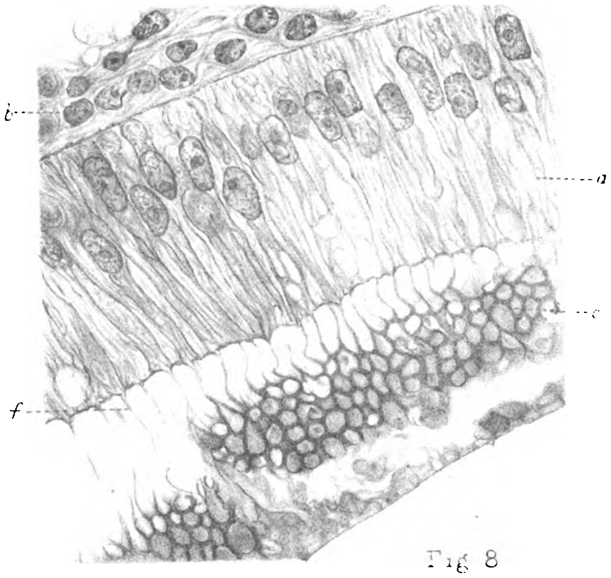


Fig. 6.

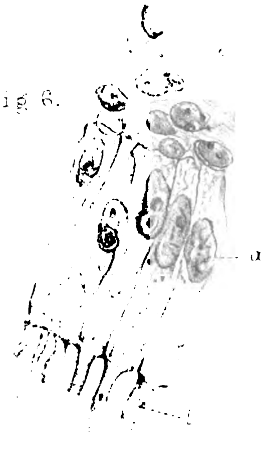


Fig. 7. x [illegible]

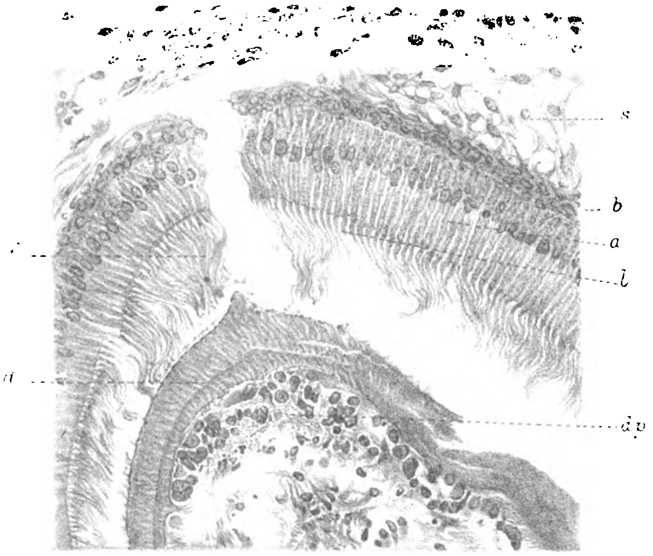
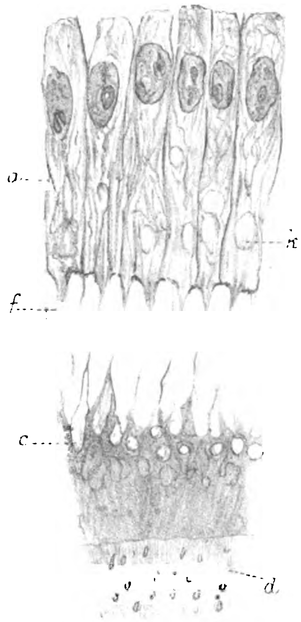


Fig. 8



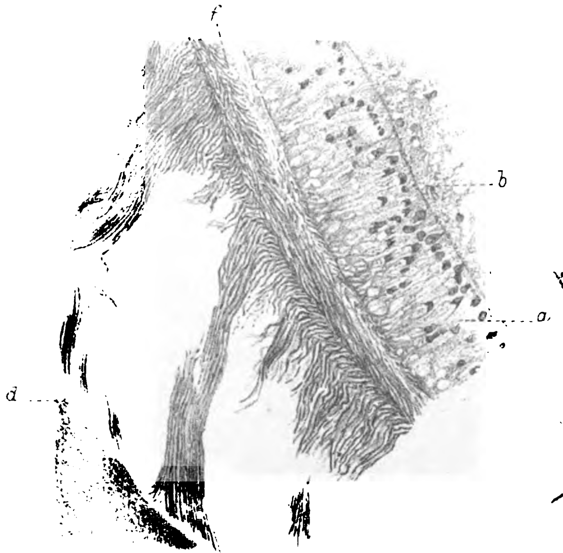
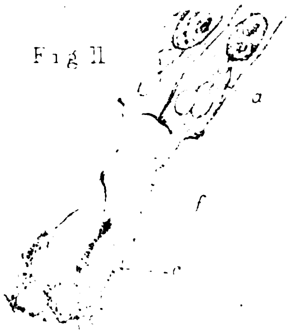
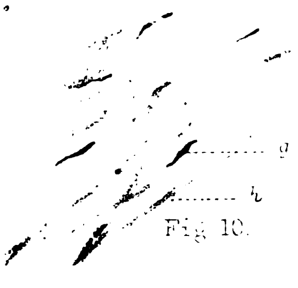


Fig. 9. x 250

Fig. 11





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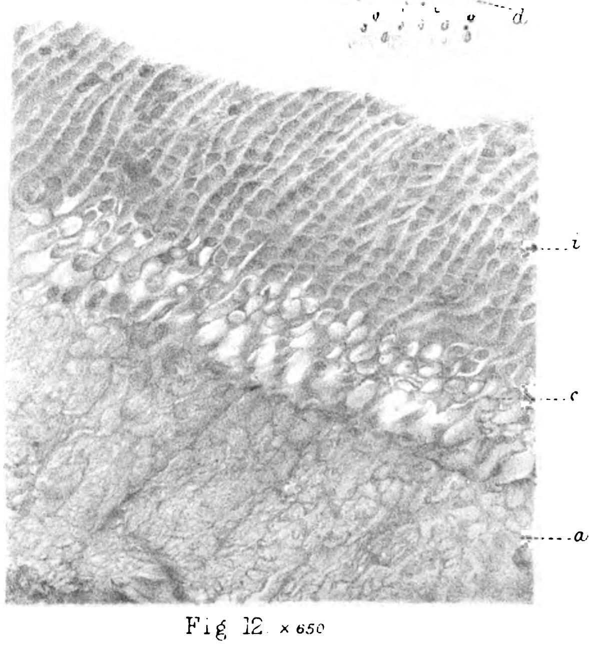


Fig. 12. x 650

West, Newman lith.

Fig. 1.

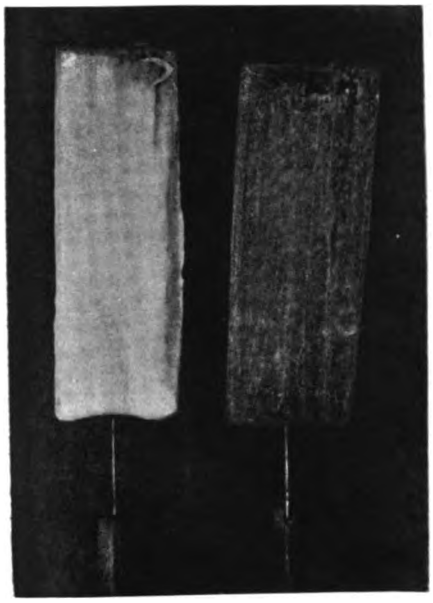


Fig. 2.

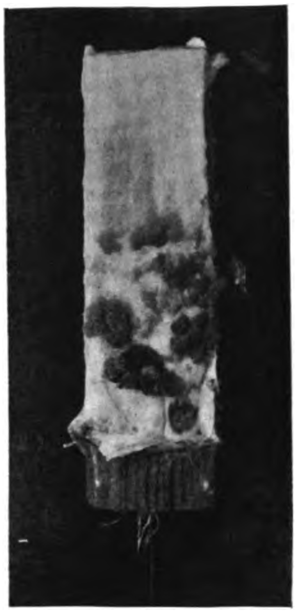
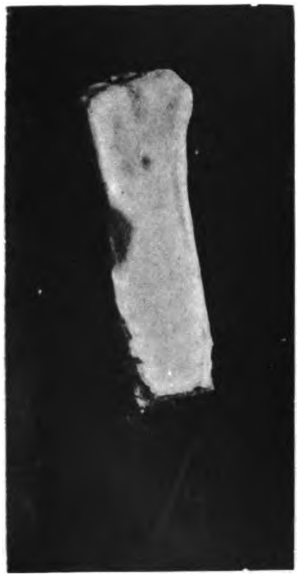


Fig. 3.



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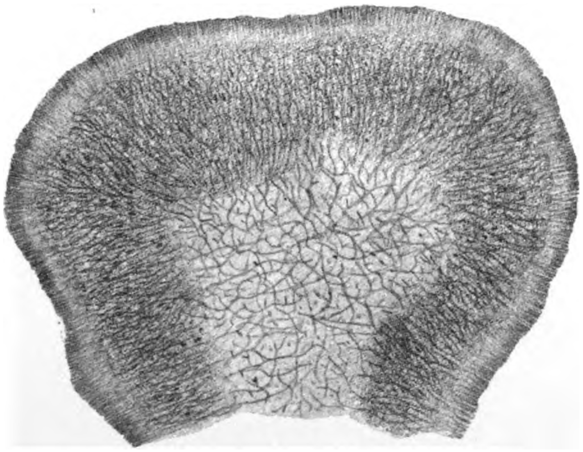

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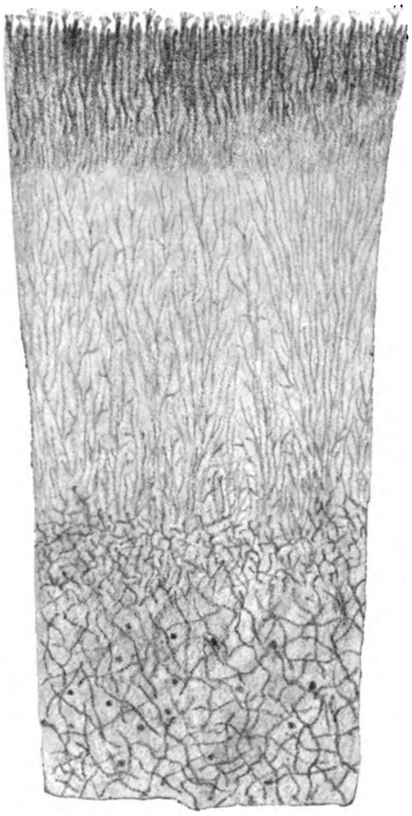

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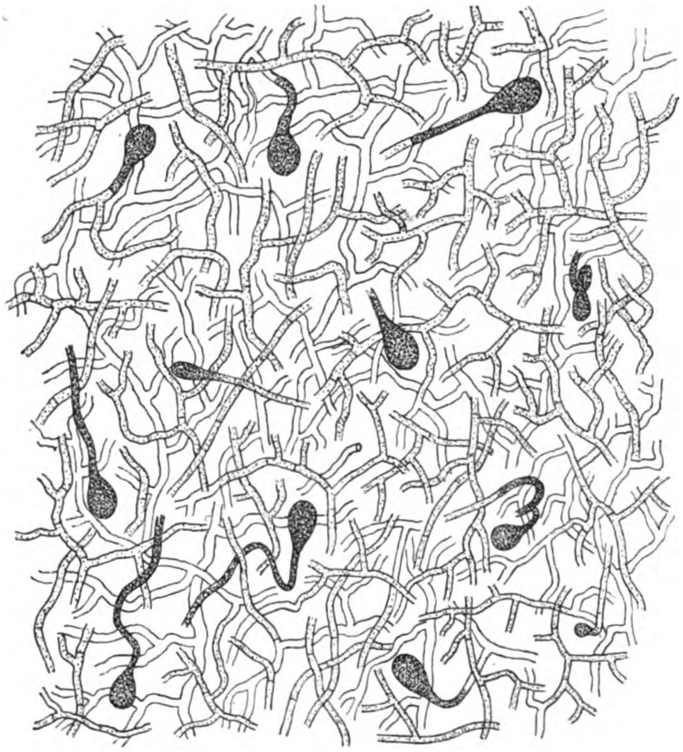


Fig 7

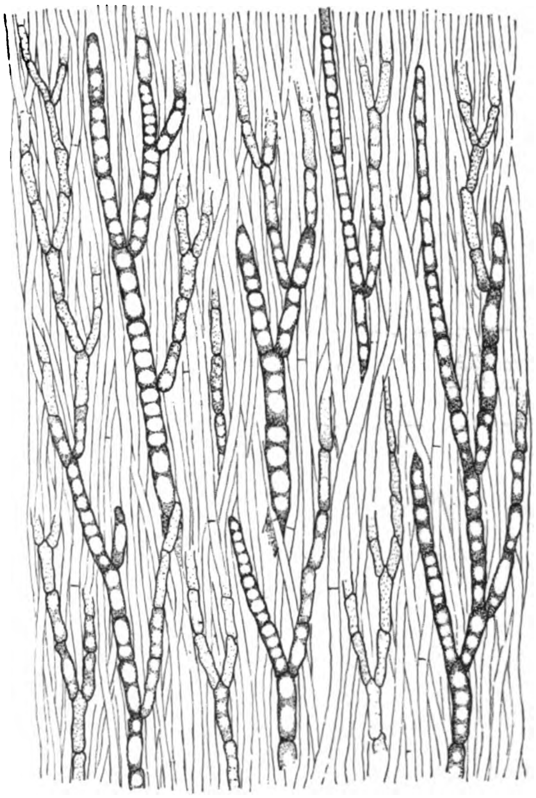


Fig. 8.

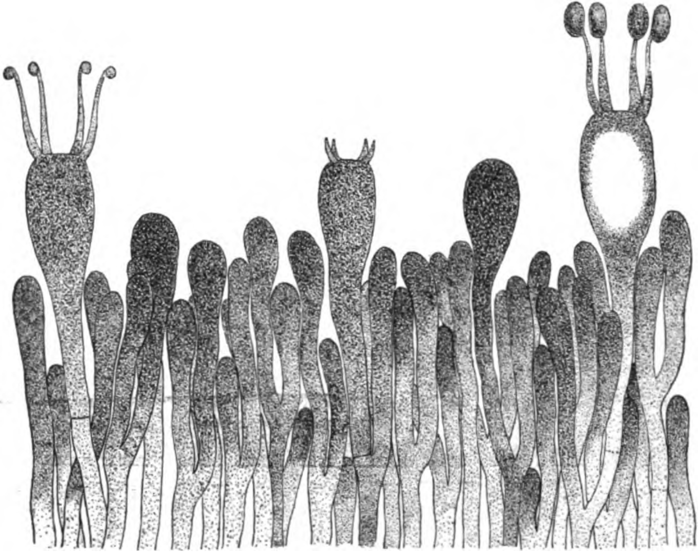


Fig. 9.

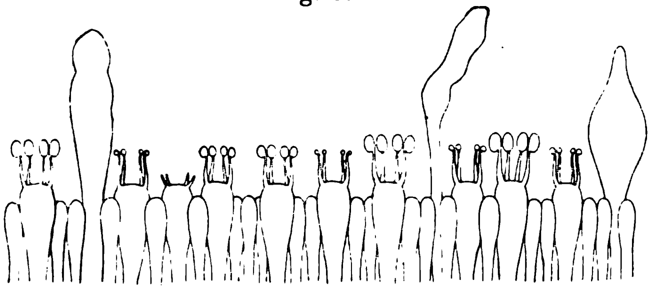
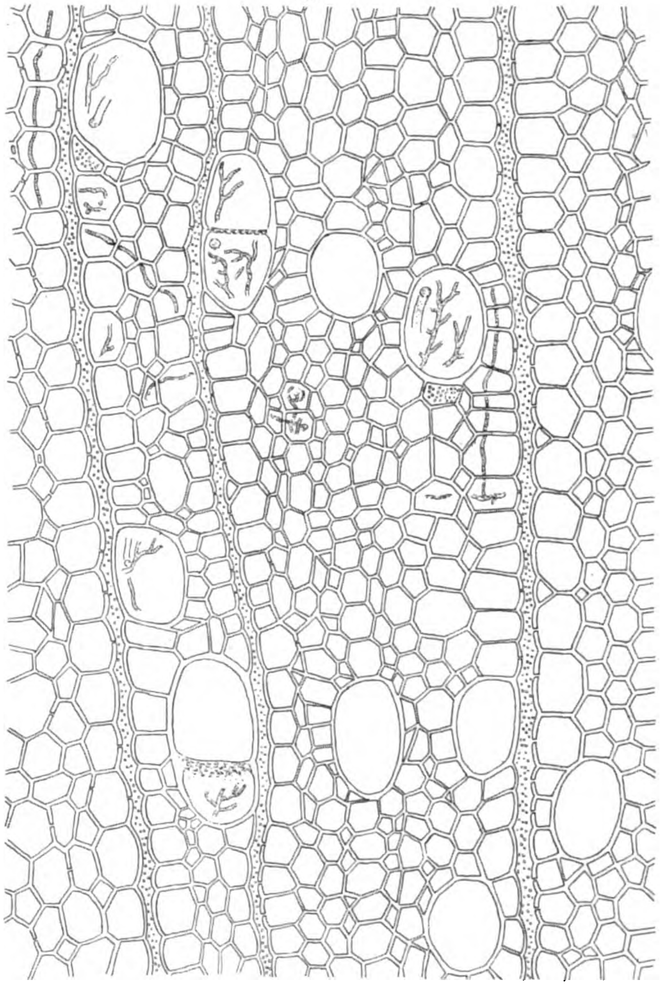


Fig. 10.



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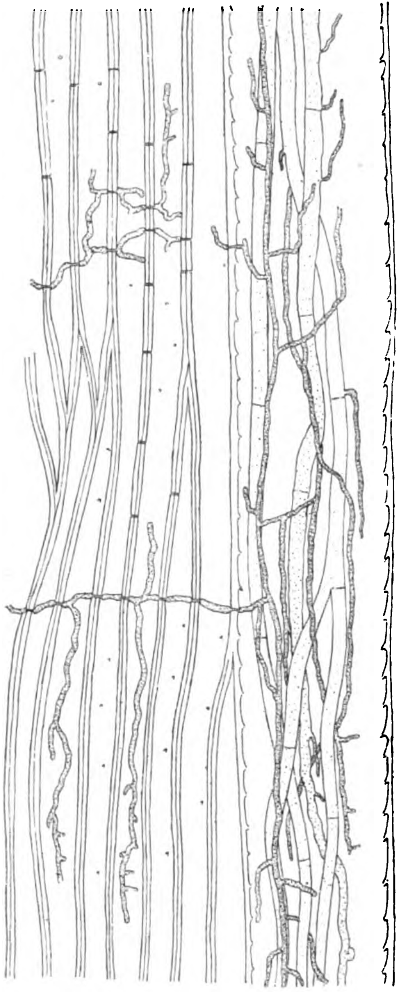
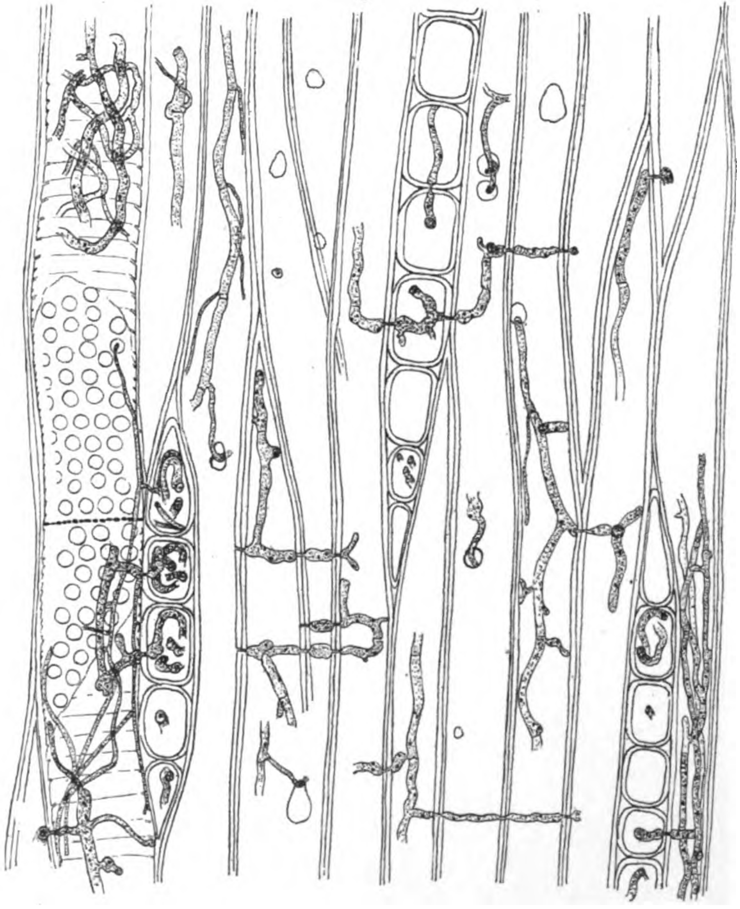


Fig. 12.



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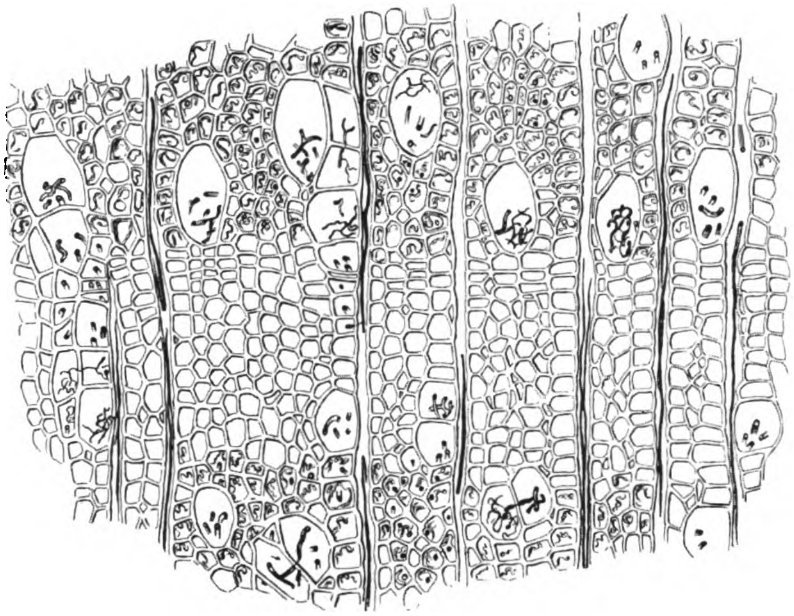

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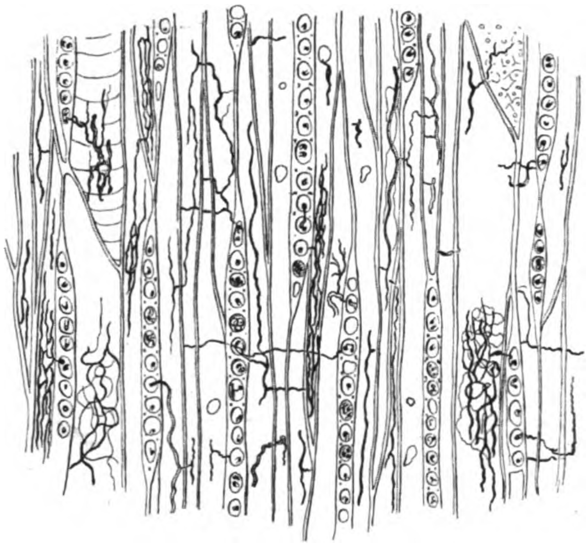

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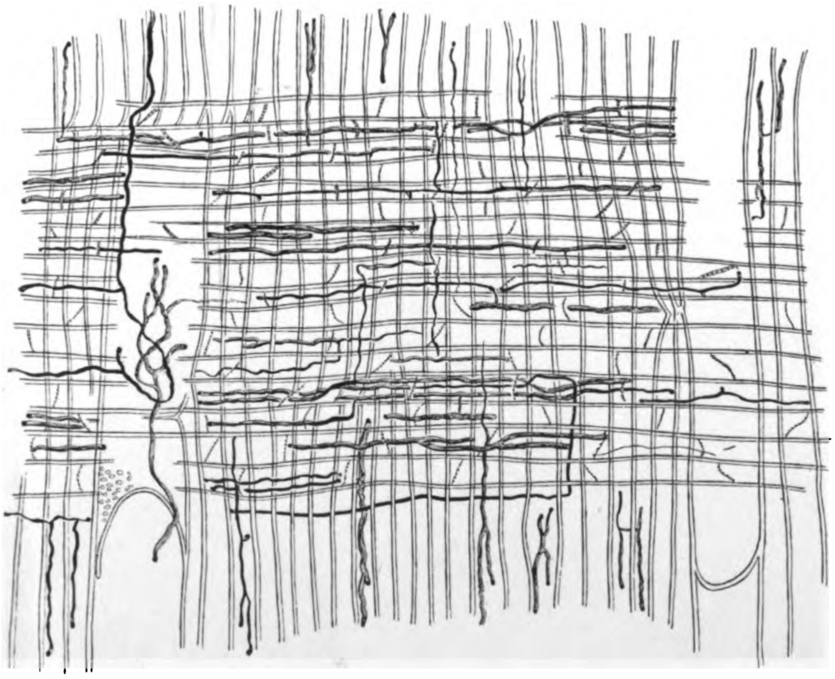
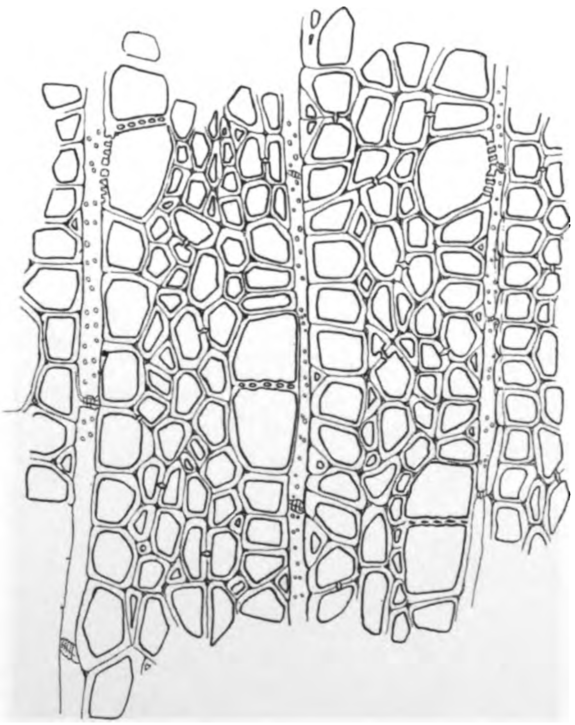


Fig. 16.



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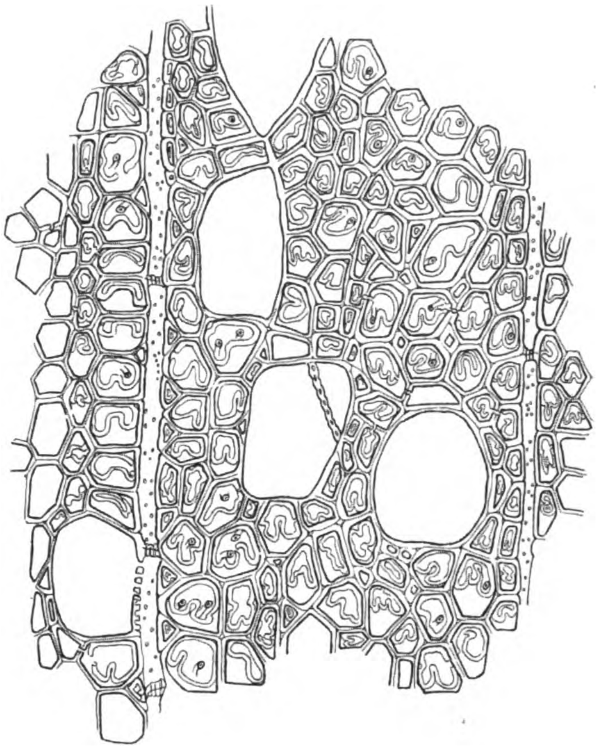

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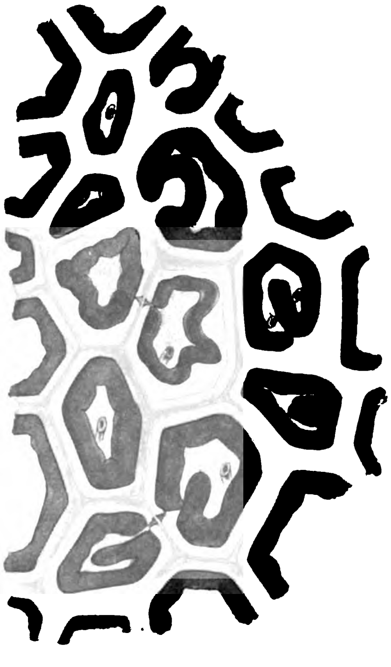
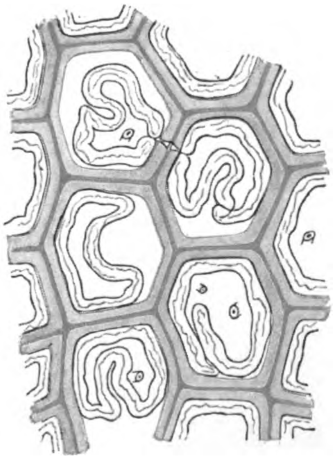
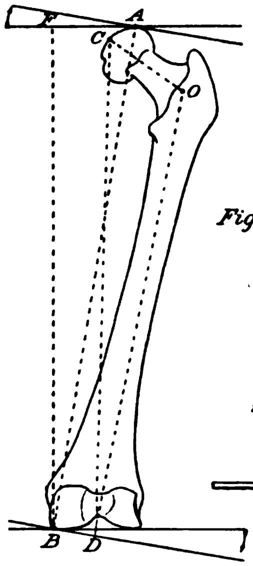


Fig. 19.





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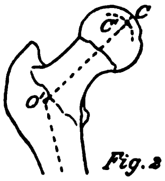
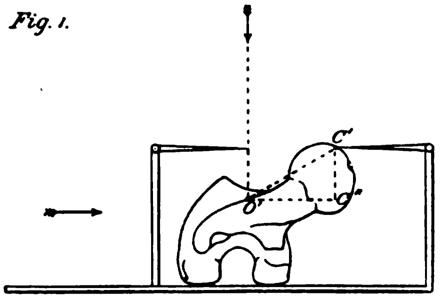


Fig. 2



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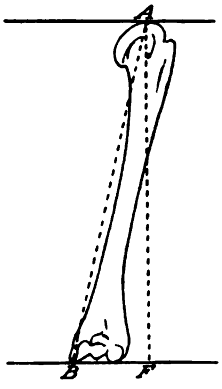

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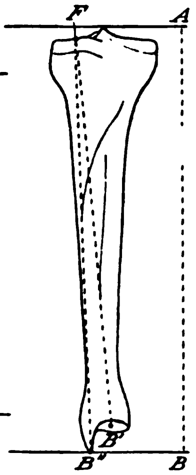

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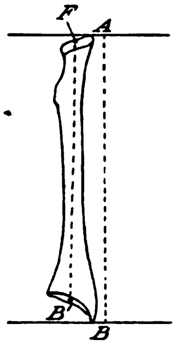

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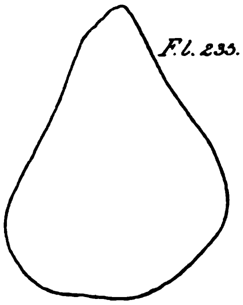

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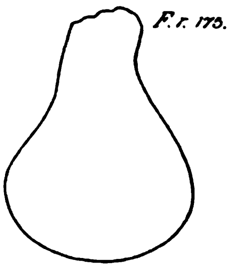

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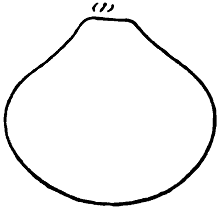

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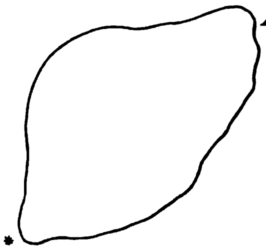

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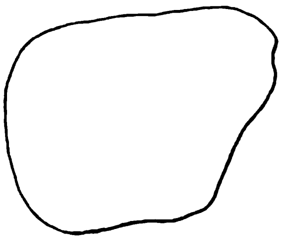

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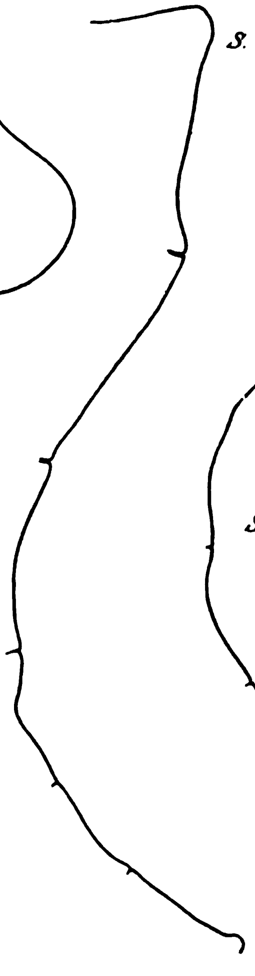

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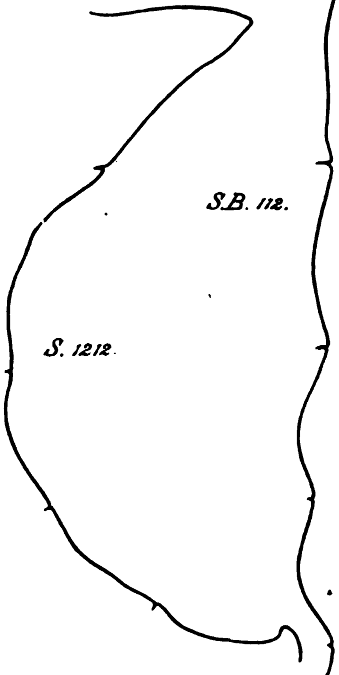

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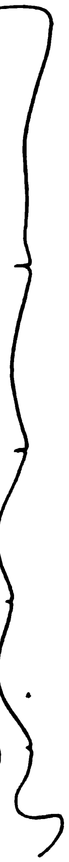

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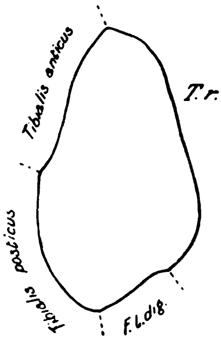

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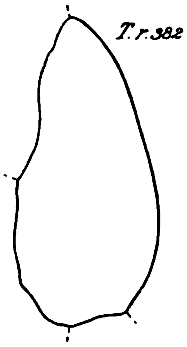

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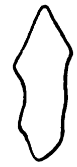

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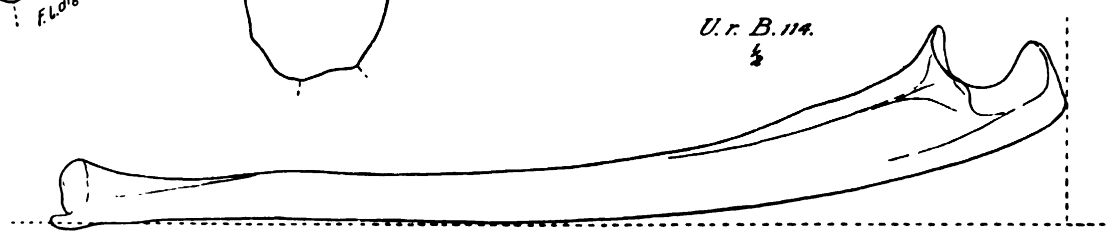

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